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Kolpondinos, Martina Z ; Glinz, Martin

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GARUSO: a gamification approach for involving stakeholders outside organizational reach in requirements engineering

Martina Z. Kolpondinos[1] · **Martin Glinz**[1]

Abstract
Stakeholder participation is a key success factor of Requirements Engineering (RE). Typically, the techniques used for identifying and involving stakeholders in RE assume that stakeholders can be identified among the members of the organizations involved when a software system is ordered, developed or maintained—and that these stakeholders can be told or even mandated to contribute. However, these assumptions no longer hold for many of today's software systems where significant stakeholders (in particular, end-users and people affected by a system) are *outside organizational reach*: They are neither known nor can they easily be identified in the involved organizations nor can they be told to participate in RE activities. We have developed the GARUSO approach to address this problem. It uses a strategy for identifying stakeholders outside organizational reach and a social media platform that applies gamification for motivating these stakeholders to participate in RE activities. In this article, we describe the GARUSO approach and report on its empirical evaluation. We found that the identification strategy attracted a crowd of stakeholders outside organizational reach to the GARUSO platform and motivated them to participate voluntarily in collaborative RE activities. From our findings, we derived a first set of design principles on how to involve stakeholders outside organizational reach in RE. Our work expands the body of knowledge on crowd RE regarding stakeholders outside organizational reach.

Keywords Requirements engineering · Stakeholder participation · Stakeholder motivation · Gamification

1 Introduction

The success probability of a software system strongly depends on the stakeholders' participation in RE activities [1]. Stakeholders are persons or organizations who influence a system's requirements or who are impacted by that system [15]. Current RE techniques effectively support the participation of stakeholders in the elicitation and prioritization of requirements for systems or products that are built for a dedicated community of users. The stakeholders of these systems are, typically, members of the organizations that commission or build the systems or of easily identifiable related organizations such as subcontractors or regulation agencies. RE experts can identify these so-called *stakeholders within organizational reach* rather straightforwardly, request them to participate in the elicitation and prioritization of requirements, and instruct them how to do so.

In recent years, globally available systems with thousands or even millions of users have emerged. Popular applications such as Instagram or Spotify are examples of such systems. The stakeholders of these systems are numerous, location-independent and highly heterogeneous. Most of them are neither members of the organizations that commission or build the system, nor of any well-known related organizations. We call these stakeholders *stakeholders outside organizational reach*, hence. They can neither be identified straightforwardly nor can they be told to participate in RE activities; they need to be *motivated* to contribute voluntarily.

Existing RE approaches try to deal with stakeholders outside organizational reach by using established techniques such as online polls, questionnaires or working with pilot customers. More recently, also crowd-based approaches have been proposed [19]. However, those approaches neither sufficiently address the challenge of identifying stakeholders

✉ Martina Z. Kolpondinos
kolpondinos@ifi.uzh.ch

Martin Glinz
glinz@ifi.uzh.ch

[1] Department of Informatics, University of Zurich, Binzmühlestrasse 14, 8050 Zurich, Switzerland

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outside organizational reach, nor do they provide means to enable and motivate stakeholders outside organizational to collaborative participation of in RE activities (see Sect. 2).

In our research, we address these two challenges. The GARUSO approach provides (1) a strategy for identifying stakeholders outside organizational reach, and (2) a social media platform that enables large-scale collaborative elicitation and prioritization of requirements, using gamification for motivating stakeholders outside organizational reach to participate.

In this article, we present the GARUSO approach, expanding our previous research on stakeholders outside organizational reach regarding the design of an effecive motivation concept [26] and corresponding gamification algorithms [25]. Our evaluation shows that the GARUSO approach actually works. In a field study, it attracted 726 visitors; 244 of them are potential stakeholders of whom 63 can be considered stakeholders outside organizational reach. Thirty-two of these stakeholders participated in the collaborative elicitation and prioritization of requirements on the GARUSO platform.

The article has four contributions: (1) We create a strategy for identifying stakeholders outside organizational reach based on the results of an exploratory study. (2) We provide a comprehensive description of the architecture and the user interface of the GARUSO platform. (3) We empirically demonstrate the effectiveness of the GARUSO approach. (4) We derive a first set of design principles for the identification and participation of stakeholders outside organizational reach.

The remainder of this paper is structured as follows: Sect. 2 gives context information and motivates our research. Section 3 presents our research questions. Section 4 investigates the identification of stakeholders outside organizational reach. Section 5 presents the GARUSO platform. In Sect. 6, we evaluate the GARUSO approach and derive a set of design principles from the results. Section 7 concludes the paper.

2 Context and motivation

A successful software system satisfies social and technical requirements [16]. Moreover, it should consider requirements that support sustainable development [34]. To meet these success criteria, requirements are not just collected, but elicited and prioritized.

Requirements elicitation is a complex recurrent process of seeking, uncovering, acquiring and elaborating requirements of a software system [14, 65]. Furthermore, RE experts need to prioritize the elicited requirements according to specific criteria to decide which ones to consider [60]. A broad spectrum of RE techniques exists to support these RE activities. However, they are limited with respect to stakeholders outside organizational reach.

2.1 Stakeholders outside organizational reach

Ubiquitously available software systems such as popular apps which have a large and diverse user community and are embedded in a real-world context typically have large numbers of stakeholders outside organizational reach. Failing to engage these stakeholders in RE processes increases the risk of overseeing technological trends, missing valuable knowledge and losing potential consumers [42].

Market-driven RE [52, 56] as well as crowd-based RE approaches [19, 20, 48] are primarily designed for feedback gathering from existing customers and users. These approaches are valuable for eliciting requirements from stakeholders outside organizational reach in the context of evolving an existing system. However, they do not address the challenge of identifying stakeholders outside organizational reach. Neither do they specifically support the development of new system nor the collaboration among the participating stakeholders, although collaboration among heterogeneous stakeholders is known to be essential (see Sect. 2.2 below).

The StakeSource approach by Lim et al. [36] supports the identification of a heterogeneous crowd of stakeholders. It uses a technique called snowballing [17], where already identified stakeholders identify further stakeholders. This approach works for stakeholders both inside and outside organizational reach. However, it does not support the identification of the initial stakeholders who then will identify new ones.

The problem of selecting representative samples from a target population when conducting opinion polls has similarities to the problem of identifying stakeholders outside organizational reach. However, for stakeholders outside organizational reach, the focus is on finding a large number of heterogeneous stakeholders who can be motivated to participate in a collaborative RE endeavor, rather than on finding some representative sample.

2.2 Collaboration

Given the ubiquitous and embedded context of today's systems and the fact that stakeholders rarely share the same needs [33, 62], collaboration and consensus finding are essential [47]. Consequently, collaborative requirements elicitation and prioritization techniques have been developed. For example, WikiWinWin [62] provides the possibility to collaboratively brainstorm needs and rate them with respect to different predefined criteria such as business importance and ease of realization. Lohmann et al. [39] have developed a Web platform that enables stakeholders to share

needs and rate or vote on needs shared by other stakeholders. Similarly, with respect to massive user involvement, Liquid RE [29] suggests to empower stakeholders to delegate their vote to others.

While the existing social media-based RE platforms provide support for large-scale collaboration, they assume that the collaborating stakeholders are known and can be told to participate, which is not the case for stakeholders outside organizational reach. Hence, we need a means for motivating stakeholders to participate voluntarily in platform activities. *Gamification* provides such a means.

2.3 Gamification

Gamification is a concept that suggests the use of game elements such as points or levels in non-game contexts [8]. Its purpose is to harnesses the motivational power of games and apply it to real-world problems [35]. Over the last years, research in RE has shown that gamification has the potential to positively affect the quantity and quality of requirements [12] and support collaboration in group elicitation approaches [57].

Recent results by Lombriser et al. [40] also strongly indicate that stakeholders support the elicitation process on a digital platform more effectively and creatively if they are motivated with game elements. Moreover, Dalpiaz et al. [7] have found that the investigations on how to apply gamification in RE are evolving toward the engagement of crowds of stakeholders.

All these gamification approaches, however, focus on stakeholders *within* organizational reach. They do not provide any means to instruct the stakeholders independently of RE experts on how to participate on the platform. Also, their underlying motivation concept assumes that the stakeholders can be told to participate, which is not the case for stakeholders outside organizational reach. In particular, the motivation concepts are not tailored to different personality aspects and as such do not address the high heterogeneity of stakeholders outside organizational reach. Hence, applying an approach designed for stakeholders within organizational reach in a context with stakeholders outside organizational reach is unlikely to be successful with respect to motivation.

Kankanhalli et al. [30] state that neglecting how people can be motivated or randomly applying gamification bears the risk of damaging their inherent motivation. This underlines the need for a well-designed motivation concept and suitable algorithms for controlling achievements such as earning points or gaining access to new levels.

In our previous research, we have contributed a stakeholder motivation concept with focus on stakeholders outside organizational reach [26] and investigated the influence of gamification algorithms on the collaborative prioritization of requirements [25].

2.4 The SmaWoMo system

For the studies that we conducted to develop and evaluate the GARUSO approach, we needed a software system for which we could identify stakeholders and let them collaboratively support the elicitation and prioritization of requirements on the GARUSO platform. For this purpose, we used a software system which is part of a smart living project on energy efficiency [10] at Empa, the Swiss federal research institute for materials science and technology. One of the goals of this project is to transform the mechanical energy generated by people while using workout equipment into electricity. To increase the electricity production, a software system is embedded in the workout equipment to motivate people toward using such enhanced workout equipment. We call it the *Smart Workout Motivation (SmaWoMo)* system in the remainder of this paper. Furthermore, the SmaWoMo system should increase the gym members' understanding of producing electricity by providing fun experiences. Note that neither the authors of this paper nor their university (the University of Zurich, UZH) were involved in the development of the SmaWoMo system as stakeholders, developers or decision makers. The role of the first author was to independently elicit requirements for the SmaWoMo system.

3 Research goal and research questions

Our research goal is to develop and evaluate the GARUSO approach with respect to the identification and participation of stakeholders outside organizational reach in RE.

To achieve this goal, we address three research questions.

RQ1. *How can we identify stakeholders outside organizational reach over diverse online channels?*

Stakeholders outside organizational reach cannot just be identified straightforwardly by RE experts. So we need to create a strategy to identify them. Therefore, we explored over which online channels and with which distribution and advertising means we can reach stakeholders outside organizational reach among a globally distributed crowd of unknown people. For answering RQ1, we performed an exploratory study (Sect. 4).

RQ2. *How can we build a platform that supports the collaborative participation of stakeholders outside organizational reach in eliciting and prioritizing requirements?*

Stakeholders outside organizational reach form a distributed group of people who, in most cases, do not know each other. Hence, a platform is needed where they can meet and collaborate. As these people can neither be told to participate in RE activities nor be instructed on how to participate, the platform must provide mechanisms that motivate the stakeholders to participate voluntarily and explain them how to participate. For answering RQ2, we used a constructive

approach: we designed the architecture of the GARUSO platform and implemented it prototypically (Sect. 5).

RQ3. *How effective is the GARUSO approach in attracting stakeholders outside organizational reach, and supporting the collaborative elicitation and prioritization of requirements by these stakeholders?*

For answering RQ3, we performed a field study in the wild. We first used the GARUSO stakeholder identification strategy (which is based on the answers to RQ1) for identifying stakeholders over diverse online channels. We then studied the activities of the identified stakeholder on the GARUSO platform (Sect. 6). We concentrated on the effectiveness of the GARUSO platform, answering sub-questions such as how many identified stakeholders participated on the GARUSO platform (Sect. 6.4.3), how and how long they interacted on the platform (Sect. 6.4.4), and how they perceived the GARUSO platform (Sect. 6.4.5).

Evaluating the quality of the elicited requirements is beyond the scope of this article. However, we provide as sample of the requirements to give an idea of the shared content (Sect. 6.2).

4 Toward a strategy for identifying stakeholders outside organizational reach (RQ1)

In this section, we describe an exploratory study that we conducted to investigate the potential of various online distribution channels with respect to the identification of stakeholders outside organizational reach.

4.1 Study design

The goal of the study was twofold. Primarily, we wanted to explore the suitability of different online channels for the identification of stakeholders outside organizational reach. Additionally, we developed an approach to segment the community of potential stakeholders according to player types [2–4] and wanted to test this approach empirically. Player types are considered the same construct as personality traits, but within the context of virtual environments and gamification [13]. We used player types to create personas for which we then designed online advertisements that we distributed over the online channels.

The method we applied was to observe distribution patterns and return rates of an online questionnaire that we injected in the different online channels.

To identify stakeholders outside organizational reach, we followed three strategies. (1) We selected a variety of online channels for the initial distribution. (2) We targeted the community of potential stakeholders with persona-based advertisements. (3) We enabled further distribution of the questionnaire by snowballing [17].

The online questionnaire that we created elicits requirements for the SmaWoMo System (see Sect. 2.4). It consists of a total of 21 questions.[1] The questions were re-used from an online survey that we had designed in the framework of a research partnership with Empa, the Swiss Federal Laboratories for Materials Science and Technology. Technically, the questionnaire was built with Unipark[2] which is an online survey tool. Unipark provides a unique URL per questionnaire that can be customized, enables the surveyees to participate with mobile and desktop devices and provides multi-language support.

For every initial distribution over an online channel, we created a copy of the questionnaire with a unique URL. This way we were able to trace every returned questionnaire to the channel where that copy of the questionnaire had been injected initially.

4.2 Selection of online distribution channels

To support the identification of stakeholders outside organizational reach with respect to different online media contexts, we considered two types of stakeholders: stakeholders who have a direct interest in the system for which the requirements are elicited and indirect stakeholders. The latter are stakeholders who do not necessarily have a direct interest in the system for which the requirements are elicited, but show an interest in topics related to it [24]. For example, these stakeholders might be curious about effects caused by using the system or have an interest in the system because of their involvement in similar technologies.

To distribute the questionnaire, we selected six typical online channels:

- Facebook and Google+ to reach people who are SNS members with a focus on social topics,
- LinkedIn and Xing to reach SNS members with a business focus,
- Google AdWords as a widely used online advertising channel,
- The official e-mail service of the University of Zurich (UZH), where we obtained permission to distribute the questionnaire to about 20,000 students and staff.

[1] The questionnaire is available under: https://figshare.com/s/4da2e2c4469bc590a97c.

[2] https://www.unipark.com/en/.

4.3 Targeting potential stakeholders

SNSs, typically, have highly heterogeneous users with different backgrounds. Therefore, we segmented the potential stakeholders with respect to the SmaWoMo system. Firstly, we used a keyword search to identify *groups* in the SNSs with a potential interest in the SmaWoMo system. In total, we found 48 groups: 11 on Facebook, 12 on Google+, 13 on LinkedIn and 12 on Xing. Secondly, we defined *personas* to address the challenge of not knowing who the stakeholders outside organizational reach are and created advertisements based on these personas to address them. We used player types [2–4] to define the personas, as they are similar to personality traits (see Sect. 5.3). People typically have one dominant player type at any point in time while showing tendencies of other player types [21, 43]. They can, for example, be driven by the possibility to collect points (dominant achiever player type) and, to a minor extent, also enjoy exploring the virtual world (minor explorer player type). We defined four personas, based on the four player types *achiever*, *explorer*, *killer* and *socializer* (see Table 1). As the *socializer* type is dominant in most people [64], it is represented by two personas. For each of the personas, we created a claim which we combined with an image to create an advertisement. Figure 1 visualizes these so-created online advertisements.

For the Google AdWords campaign, we selected keywords from the keyword idea pool, which lists keywords that are automatically generated by Google AdWords with respect to the text that we used for our advertisement. The keywords included, for example, *electricity generation*, *alternative energies*, *fitness* and *workout*.

With respect to e-mail distribution, we applied for permission to distribute the questionnaire to as many UZH students and academic staff members as possible.

4.4 Enabling snowballing

For reaching further stakeholders by snowballing [17, 37], we enhanced the questionnaire with share buttons of social

Table 1 The personas we created based on player types to segment the users of SNSs

Persona	Player type	Age	Description	Inherent motivation	Stake in SmaWoMo
Giuseppe	Killer	22	Giuseppe finished his apprenticeship a few years ago and just got his bachelor degree in international economics. Next week, he starts his first job as a salesman in a company that sells high-end products to an exclusive clientele. He is very eager to get the highest selling ratio among his co-workers in order to quickly move up the corporate ladder. Since he believes that one's appearance plays a key role in personal success, he cares a lot about his body shape.	Be the best	Gain power and control in business
Zoi	Explorer Socializer	35	Zoi has a degree in computer science and works as a senior user experience strategist for a large USA company in the entertainment industry. She is curious and open-minded and does neither like monotonous work nor routines. Instead, she prefers to challenge herself to get out of her comfort zone by trying new things and to interact with people of different backgrounds. Due to the high cognitive load and the mostly seated position in her job, she started to work out.	Discover new things and people	Reach and maintain physical balance Connect and interact with others
Heather	Socializer	55	Heather has her social life in London and works as a CEO of an international high-tech company in Singapore. Due to the responsibilities that come with the job, she meets at least twice a month with the English trade association in London. While she is in London, she visits her friends and family. Keeping a healthy life-work balance is very important to her. Her busy schedule makes this increasingly difficult, however. As most of her friends and family are members of the same gym, she decided to become a member at this gym, too.	Connect with family and friends	Meet family and friends
Hans	Achiever	65	Hans retired recently. Before, he had worked as a construction worker in the same company for almost 50 years. He is ambitious to be good in what he does and never stops until he reaches his goals. A few months ago, he got interested in alternative ways to produce electricity. So far he has installed a solar panel on the roof of his house. As a next step, he wants to combine it with a small wind turbine. To keep his body fit for the heavy work, he started going to the gym.	Master challenges	Achieve personal goals outside the gym

Fig. 1 The online advertisements that we designed with respect to the created personas (see Table 1)

media channels that enabled the participants to promote the questionnaire URL on these channels.

4.5 Distribution of information

We created identical copies of the questionnaire with unique URLs for each of our six distribution channels. Distribution took place between May 4 and June 3, 2016.

Table 2 shows how we distributed the URLs of the corresponding questionnaire copies to the SNS groups that we had identified before. For each group, we chose the persona-specific advertisement which fitted best for that group. We considered each group only once to limit the risk of being excluded due to the impression of spamming. Additionally, we distributed an advertisement showing a combination of all four advertisements as well as the advertisement for Zoi as a socializer to the public threads of Facebook, Google+ and LinkedIn. As Xing does not allow to post images on the public thread, we used one textual version of the advertisements for the public thread of Xing.

To distribute the questionnaire with Google AdWords, we used the following text: *"Generate Electricity @ The Gym: How much chocolate does your mobile need to run? Discover more."* The total cost for the Google AdWords campaign was about 124 USD.

For e-mail distribution, we obtained permission to distribute the questionnaire to about 20,000 UZH students and staff members. Although the students and staff are part of the same organization as the survey authors, we consider them to be a good model for stakeholders outside organizational reach: They are numerous, heterogeneous (for example, with respect to their study subjects and interests) and, due to the absence of any contractual obligations to support our research, they can neither be instructed on how to participate nor told to actually do so. We used the e-mail subject "*Evaluation of motivational aspects for the generation of electricity at the gym*" and started the e-mail with three questions: *"Where can we as individuals contribute to energy efficiency? How can software systems support and motivate us in doing so? What are the requirements of these software systems?*" Furthermore, we described the SmaWoMo system and made clear that the surveyees neither have to be gym members nor to do sport at all. The e-mail was sent with an explicit statement that we had obtained permission to send it and that participation was anonymous.

Table 2 Distribution of questionnaires to social network groups

Online advertisement for persona	SNS context			
	Social		Business	
	Facebook	Google+	LinkedIn	Xing
Giuseppe	1	2	2	2
Zoi (explorer)	4	4	4	3
Zoi (socializer)	2	2	2	2
Heather	2	2	1	1
Hans	2	2	4	4
Total	11	12	13	12

4.6 Metrics and data analysis

We ran the study from May 4, 2016 to December 31, 2016. We chose this long study period for observing the visitors' behavior over time. Unipark stores the questionnaire answers together with meta-information such as the time of access and a unique identifier in one data set per user and questionnaire.[3] It applies cookies to identify returning users and redirects them to the last answered question. Thereby, it updates the data set that was created at a user's first visit. Due to this process, we consider the number of data sets to be a valid metric for the number of *visitors*. To identify stakeholders of the SmaWoMo system among the visitors, we considered the number of answered questions, as done in previous research on crowdsourcing [28]. *Potential stakeholders* are visitors who answered at least the first part of the questionnaire, which includes the introductory and demographic questions. *Stakeholders* are the ones who completed the questionnaire.

To investigate the snowballing approach, we determined how many visitors accessed the questionnaire through a channel which was different from the one where that questionnaire copy had been originally injected by

[3] The data is available under: https://figshare.com/s/d3abc24c965395abb6fd.

us. We identified the actual access channel by asking the participants in the first question of the questionnaire about the channel where they had found the questionnaire. The channel from which the accessed copy originally came can be traced easily as each of the distributed copies has a unique URL.

4.7 Results

In total, 544 visitors accessed the questionnaire copies that we had distributed over the online channels mentioned above. 495 of these visits (91%) occurred within the first month of the study period. In the second month, we had 45 visits (8.3%), and only four visits (0.3%) occurred in the remaining six months. 471 visitors answered the initial questions. This fact qualifies them as potential stakeholders according to our definition. 402 people of those 471 completed the questionnaire, which means that we can consider them as stakeholders outside organizational reach. Figure 2 shows the results with focus on the SNSs (a) and the other online channels that we had used (b).

We attracted a surprisingly low number of visitors through SNSs and Google AdWords: 38 and 33, respectively. In contrast, the e-mail distribution yielded 473 visits. With respect to the number of identified stakeholders outside organizational reach, the e-mail distribution was also the most successful one: there, 80% of the visitors completed the questionnaire, while only 58% of the visitors from SNSs and zero from the Google AdWords did so. The latter might be due to our very limited budget for the AdWords campaign.

When analyzing the results for the SNSs (Fig. 2a), we observed major differences between the groups and the public threads. For Facebook, the public thread was by far more successful in attracting visitors than the groups, while for LinkedIn and Xing, it was the opposite.

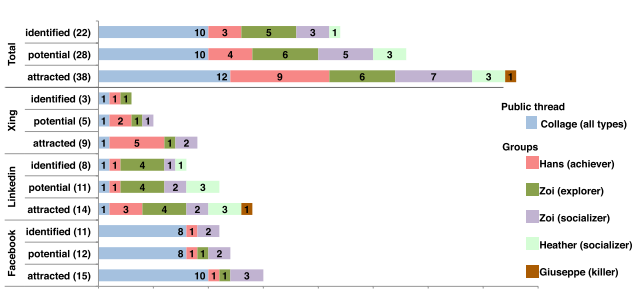
With respect to the persona-specific advertisements that we use in the SNS groups, we observed that the advertisements for Hans (achiever) attracted most visitors, while the one for Zoi (explorer) identified the highest number stakeholders among the visitors. In contrast, the advertisements for Heather (socializer) and Giuseppe (killer) were rather unsuccessful.

Table 3 summarizes the results with respect to the snowballing approach. It presents the numbers of cross-references between the involved channels, i.e., how many times a questionnaire copy was accessed from a channel which is different from the one on which we originally distributed the corresponding questionnaire URL. We use semicolons to separate between the results of visitors, potential stakeholders among the visitors and identified stakeholders among the potential stakeholders, respectively.

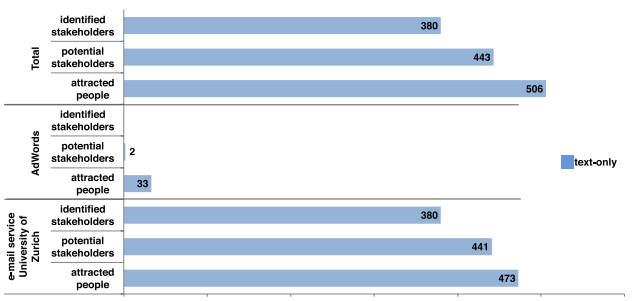
4.8 Threats to validity

External Validity. Some recipients of the e-mail might have answered the questionnaire not due to being interested in SmaWoMo, but just in order to support the researchers who had posted the survey. This "courtesy bias" might have influenced the number of responses received. However, completing the questionnaire required 20 to 30 minutes. Therefore, we think that at least the number of persons who completed the questionnaire and are considered to be stakeholders outside organizational reach for the SmaWoMo system which was not biased. Similarly, the effectiveness of the advertisements also depends on how their visual design is perceived by (potential) stakeholders. We addressed this threat by designing the advertisements with respect to player type characteristics. As this "visual perception bias" exists for all advertisements that we designed, we consider it a minor threat with respect to the study purpose.

Internal Validity. We could not post every persona-specific advertisement to exactly the same number of groups on all SNSs. This is due to the fact that (1) we only found a rather limited number of groups related to the topic of SwaWoMo, and (2) we exclusively used one advertisements per SNS group to reduce the risk of being excluded from a



(a) Results per SNS on which we used the persona-based advertisements. Our posts to Google + resulted in zero visits, hence they are omitted from the figure.



(b) Results per multimedia channel on which we did not use the persona-based advertisements

Fig. 2 Numbers of visitors, potential stakeholders and identified stakeholders per online channel

Table 3 Cross-references between channels of access as selected by the surveyees and the initial online channel used for distribution *(visitors; potential stakeholders; identified stakeholders)*

Original distribution channel	Channel of access				
	Facebook	LinkedIn	Google+	e-mail	Other
e-mail	5;5;5		1;1;1		2;2;2
LinkedIn				1;1;0	3;0;0
Xing		1;1;1			
AdWords	3;1;0	1;1;0	1;0;0		1;0;0

group (see Sect. 4.5). This affects the comparability of the numbers found for the different SNSs.

The results on the cross-references depend on how accurate the surveyees' answers were with respect to the online channel through which they accessed the questionnaire. They did, however, not gain anything by giving a faulty answer. Therefore, we argue that their self-declaration can be trusted.

4.9 Lessons learned

From the results of this study, we drew five lessons that we incorporated into the GARUSO stakeholder identifications strategy: (1) Targeted mass e-mailing is effective and should be used. (2) For SNSs, groups related to the subject of the system to be developed should be identified and the group members addressed with persona-specific advertisements to attract potential stakeholders among them. (3) The public thread should be given preference for SNSs with a social context, while in SNSs with a business focus, groups turned out to be more effective. (4) Concerning segmentation by personas, the achiever type and the explorer types yield best overall results. (5) Although snowballing turned out to be not very effective, it yields some additional stakeholders.

5 The GARUSO platform (RQ2)

The GARUSO platform is a social media platform that enables stakeholders outside organizational reach to participate collaboratively in activities which support the elicitation and prioritization of requirements. It uses gamification to motivate the stakeholders to participate voluntarily in these activities. As stakeholder outside organizational reach form a heterogeneous crowd, the GARUSO platform uses a diversified motivation concept which considers different personality aspects and their change over time [26]. In this section, we describe the architecture and the user interface of the GARUSO platform. We use the term *platform users* to denote the stakeholders who use the GARUSO platform for eliciting and prioritizing requirements.

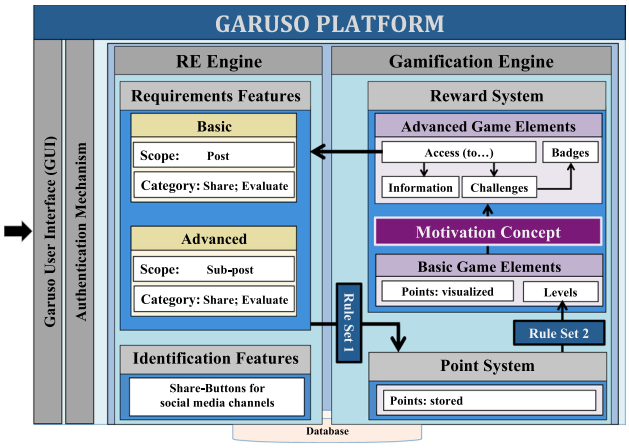


Fig. 3 The GARUSO architecture (adapted after [23]).

5.1 Overview of the architecture

Figure 3 illustrates the architecture of the GARUSO platform. The *graphical user interface (GUI)* enables visitors to register through the *authentification mechanism*. We applied a two-way mechanism to reduce the risk of malicious users. The platform users who successfully registered get access to the features of the *RE engine* and are motivated by the two systems of the *gamificiation engine*. Subsequently, we explain these two engines in more detail.

5.2 The RE engine

The *RE engine* has the two components: *requirements features* and *identification features* (see Fig. 3).

Requirements features specify the activities that can be taken on the GARUSO platform to support the elicitation and prioritization of requirements. Every activity is characterized by its *scope* (*post* or *sub-post*) and *category* (*share* or *evaluate*).

With a *post*, the platform users describe a *wish* that they have with respect to the software system for which they participate in the RE activities on the platform as well as a *benefit* that they assume to experience if the *wish* is fulfilled. To complete a post, they also need to provide the context in which they experience this *benefit* most, which they can do by selecting a benefit *label*. Figure 4 shows a screenshot of the form that has to be completed by the platform users to share a post on the GARUSO platform. It provides text fields for the *wish* part and the *benefit* part and labels to define the context of the benefit.

To strengthen collaboration, the platform users can add sub-posts to a post. A *sub-post* describes an additional *benefit* of the *wish* stated in the post to which the sub-post is added. Again this benefit requires a benefit label for the context. Hence, together a post and its sub-posts build a

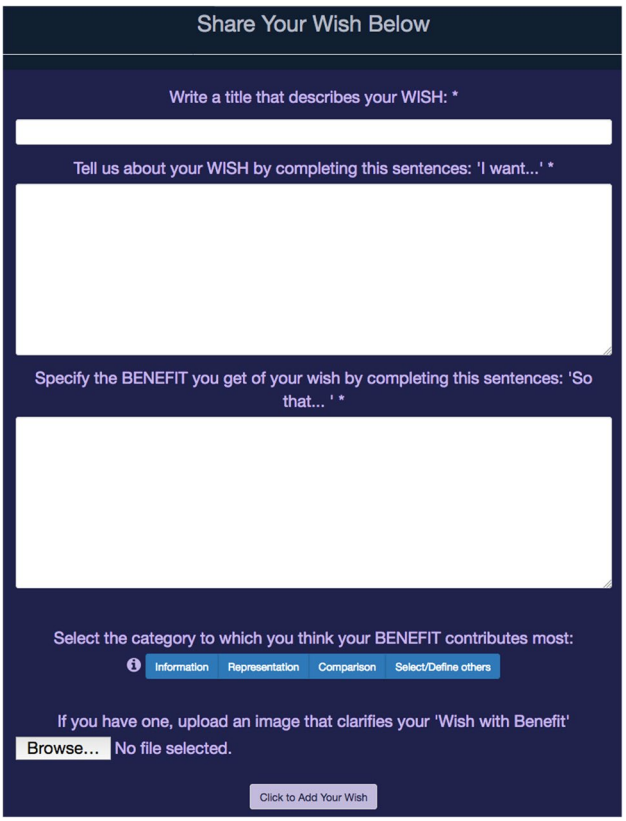


Fig. 4 Screenshot of the form used on the GARUSO platform to share a post

simplified and extendable user story that includes contextual information and has the form: *I want [wish] so that [benefit] which contributes most to [label]*, where the part *"so that [benefit] which contributes most to [label]"* can be repeated. We choose this approach as user stories contribute to the quality of requirements [41] and support the RE process when involving crowds of stakeholders [7].

To *share* a post or sub-post means that a platform user creates a post or sub-post and, at the same time, shares it with all other users of the GARUSO platform. Platform users can *evaluate* other users' posts by rating them and voting on the benefit label. They can also evaluate other users' sub-posts by voting on the benefit label of the sub-post. The platform users can change their evaluation choice at any time, which considers that their perception can change during the elicitation process as they become more familiar with the system and the application domain [65]. To limit the risk of false evaluations, they can indicate that they do not want to rate or vote a shared contribution.

As every post expresses a wish, sharing new posts contributes to the elicitation of new requirements. When evaluating posts or sub-posts, the platform users provide information on their perception of other users' requirements, which supports the prioritization process.

We conclude this subsection with the description of the benefit labels that we derived from our previous research on sustainability requirements [24] with an example for the SmaWoMo system, each. (1) *Information*: The [benefit] focuses on facts. For example, it gives information on the number of Watt hours that are produced during a workout session. (2) *Representation*: The [benefit] supports the understanding of sustainability metrics. For example, it shows how many hours a light bulb can be lit with the generated Watt hours. (3) *Comparison*: The [benefit] sets two values in relation to each other. For example, it shows how much electricity a gym member generated compared to the last time or to others. (4) *Select/Define others* enables advanced platform users (see Sect. 5.3) to create a new label and to choose among all created labels. It is replaced by *other than default* for novice users.

Identification features offer a means to identify stakeholders independently of RE experts with share buttons of social media channels. The registered stakeholders can use these buttons to invite other stakeholders over those channels to participate in activities on the GARUSO platform. This approach is inspired by the previously introduced snowballing process [38].

5.3 The gamification engine

The *gamification engine* consists of two *rule sets*, the *point system* and the *reward system* (see Fig. 3). We defined the two rule sets based on our previous research on gamification algorithms [25] for which we used an early version of the GARUSO platform.

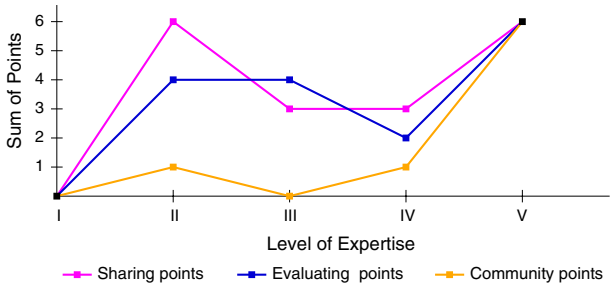
Rule set 1 and point system: *Rule set 1* connects the *requirement features* with the *point system* by translating the platform users' activities into points. Table 4 illustrates *rule set 1*. It shows for every activity that is enabled by the *requirement features* the number of points that are *earned* per point category. The point categories mirror the activity categories with *sharing points* and *evaluating points* and, furthermore, include *community points*.

- Platform users earn *sharing points* when sharing a post or sub-post.
- They earn *evaluating points* for rating or voting another platform user's shared post or sub-post for the first time.
- They earn *community points* when another platform user evaluates one of their shared posts or sub-posts or adds a sub-post to one of their posts.

The number of *sharing points* and *evaluation points* that a platform user earns after performing a corresponding activity reflects the effort that we assume is needed to perform

Table 4 Rule set 1: earned points per activity

Activity	Points to earn		
	Active		Passive
	Sharing points	Evaluating points	Community points
Share post	6		
Rate post		2	[−2;−1;0;1;2]
Vote on post benefit label		2	[−2;0;2]
Share sub-post	3		3
Vote on sub-post benefit label		2	[−2;0;2]



The intensity of the motivational trigger increases at the beginning, decreases in the middle and increases again towards the end.

Fig. 5 Rule set 2: Needed points per level

the activity. To estimate the effort, we set all activities of the same point category in relation to each other. For *sharing points*, we assume that to share a post demands the highest effort as it requires two parts of a users story; a wish and its benefit. In contrast, a sub-post only requires a benefit and as such one part of a user story. This is why twice the points are earned for sharing a post compared to sharing a sub-post. With respect to evaluation, we perceive that to rate a post and to vote on a label of a post or sub-post requires the same effort. Therefore, each of these activities results in the same number of *evaluation points*. It is important to note that *evaluation points* are only earned for the first evaluation of a post or sub-post and not for changing it, which, however, affects the *community points*.

Platform users earn *community points* when their posts or sub-posts are evaluated by other platform users. For example, if *user A* votes for a label of a sub-post shared by *user B*, *user B* earns +2 *community points*, whereas a vote against yields -2 and a neutral vote 0 *community points*. (In turn, *user A* earns +2 *evaluation points* for the first vote independently of the choice.) Compared to voting, rating facilitates a more fine-tuned evaluation with a scale of five values (see Table 4).

Rule set 2 connects the *point system* with the basic game element level of the *reward system*. It defines the number of points needed per point category to reach a level. The GARUSO platform uses five levels to define the users' expertise based on their platform activities from novice (level I) to expert (level V).

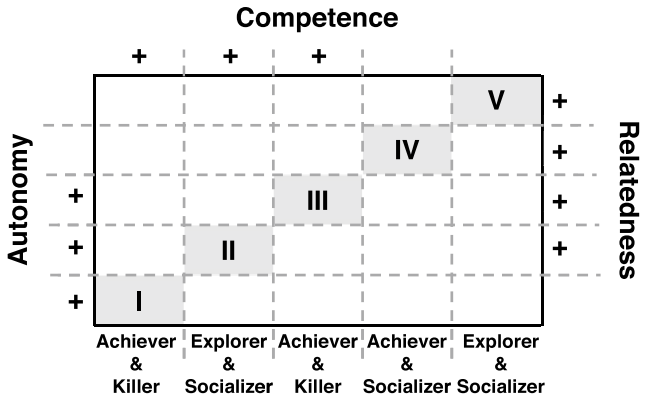
Figure 5 indicates the number of needed points per expertise level for all three point categories. For example, reaching level II requires six sharing points, four evaluation points and one community point. This means a user would, for instance, need to share and evaluate at least one post and receive a positive rating by another user (see *rule set 1*). The graph increases at the beginning, decreases afterward and increases again toward the end. This behavior was one of the key findings of our previous research [25] on the effects of gamification algorithms in RE.

Reward system and motivation concept: The *reward system* is based on the *motivation concept* which considers the high heterogeneity of stakeholders outside organizational reach and the change of motivational factors over time. It is built upon the stakeholder-centric motivation concept that we created in our previous research [26]. Its design is mainly inspired by the experiential learning theory of Kolb [32], a holistic learning theory that reflects the relationship between a person and the environment with the dual meaning of experience (p. 35): (1) *environmental* ("20 years of experience in the job"), and (2) *personal* ("experiencing joy and happiness").

The purpose of the *motivation concept* is to define the rewards of the GARUSO platform with respect to the platform users' experience. To measure *environmental experience*, we consider the theory of skill acquisition by Dreyfus [9], who states that when people follow the desire to acquire new abilities, they typically pass five stages from novice to master, whereas understanding of the domain happens in the third stage.

For measuring *personal experience*, we consider Bartle's player types [2]. *Achievers* prefer to act in the world (or system), while *killers* act on other players. *Socializers* rather interact with players, while *explorers* interact with the world (or system). Thereby, we respect personality traits, which are characteristics of people that define how they act within the social world [5]. In fact, player types are considered the same construct as personality traits; only their context is different [13]. When people act in the "real" world, they typically have one dominant personality trait together with several latent ones [58] of different intensities [13]. Research results show that this is the same with their player types [13, 21, 43, 58].

Importantly, when people get to know and better understand the virtual environment [4] or system that applies gamification [43], their player types evolve. This means that people feel differently motivated over time. To consider this



(a)

Level	Rewards				
	Non-Game Context	Hybrid Context*		Game Context	
	Requirements Features	Access to Information	Access to Meta-data	Access to Challenges	Badges
V	• Create labels		• Become a chat member		
IV		• Number of users per level • Total evaluation value per post	• Nickname of author per sub-post		
III	• Vote sub-post labels	• Number of voted sub-post labels • Vote values per sub-post label • Vote value per post label	• Nickname of author per post	• Advanced challenges	• Advanced badges
II	• Share sub-posts • Vote post labels	• Number of shared sub-post • Number of voted post labels • Date when a post was shared • Number of sub-posts per post		• Basic challenges	• Basic badges
I	• Share posts • Rate posts	• Number of shared posts • Number of rated posts • Number of users on lower and upper levels			

* We consider this a hybrid context as the rewards themselves refer to the non-game context of RE, yet, they do not directly contribute to the RE activities. Instead, they address motivational aspects, which are related to the game context.

(b)

Fig. 6 **a** Motivation concept with indicated rewards (gray area) per expertise level (I–V), player type (bottom line) and basic human needs (autonomy, competence and relatedness) where marked with +; **b** Actual rewards of the GARUSO platform based on the motivation concept shown under (**a**)

dynamic behavior, we use the two main player-type development paths by Bartle [3] and define dominant player types for each expertise level.

To measure the overall experience, which, with respect to the *motivation concept*, is a combination of the environmental and the personal one, we used the five expertise levels described above. The rewards of the GARUSO platform are defined per expertise level and as such with respect to the corresponding stage of skill acquisition and the dominant player types. In addition, they consider the theory of basic human needs by Ryan & Deci [54], which refers to the feelings of *autonomy* (being in charge), *competence* (power of free choice) and *relatedness* (being connected with others). The theory states that the more a person perceives the satisfaction of those needs when being rewarded for an activity or while performing an activity, the more the person's motivation increases toward the activity.

Figure 6a sketches the *motivation concept*. It indicates the rewards (gray areas) per expertise level (roman letters), under consideration of the most dominant player types (bottom line) and the basic human needs (side lines and top line) where marked with +. The focus on *autonomy* and *competence* on the lower expertise levels of the *motivation concept* and shift to *relatedness* for the higher levels is based on Maslow's Hierarchy of Needs [44]. For example, rewards designed for expertise level I focus on the achiever and killer player types while considering the basic human needs of *autonomy* and *competence*. Figure 6b shows the actual rewards of the GARUSO platform. The rewards of the non-game context relate to the environmental meaning of experience as they reflect the RE activities. With the rewards of the game context, we consider the personal meaning of experience. Furthermore, the hybrid context includes rewards of the non-game context without directly affecting it and addresses motivational aspects of the game context. Hence, these rewards relate to both meanings of experience. For example, revealing the platform users' nicknames gives information that considers the RE context and facilitates comparison, which has a high motivational potential.

The rewards shown in Fig. 6b are defined based on the *motivation concept* shown in Fig. 6a. As an example, we discuss the rewards on level II. According to the *motivation concept*, these rewards should focus on the explorer and the socializer player types and consider all three basic human needs. Access to basic challenges and information on the publication date of posts addresses the two mentioned player types. The two *requirements features* (*share sub-posts* and *vote sub-posts*) address the feeling of autonomy and competence. The numbers on overall activities add to the feeling of relatedness.

5.4 The GARUSO user interface (GUI)

The GUI shows the rewards described above with respect to a visualization scheme (see Fig. 7) that we created as guidance for the platform users. Figure 8 shows a screenshot of the main page of the GARUSO platform. We added roman letters to show the expertise level on which (depending on the previously introduced *motivation concept*) the GUI elements become visible. Before we describe the details with a usage scenario in Sect. 5.4.3, we discuss the visualization scheme and the onboarding process.

5.4.1 The visualization scheme

We created a visualization scheme to distinguish the GUI elements related to single activities facilitated by the *requirements features*. For this purpose, we considered the activity category and scope (see Fig. 7).

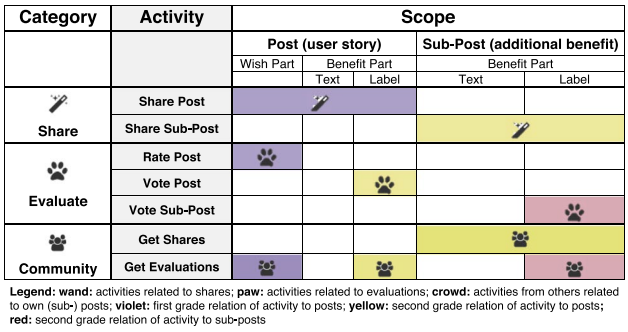


Fig. 7 Visualization scheme with icons and colors

- *Icons* indicate the activity categories. A *wand* relates to sharing activities as the sharing of posts and sub-post considers a stakeholder's wish. A *paw* represents evaluating activities as they require the click on a button. Finally, a *crowd* refers to activities of others for own contributions (see, for example, the two sidebars in Fig. 8).
- *Colors* consider the activity scopes. *Violet* refers to activities that directly affect a post such as rating. *Yellow* considers activities that indirectly affect a post such as evaluating its benefit part or sharing a sub-post. *Red* indicates activities that affect a sub-post such as its evaluation. Any other color used in the GUI has no special meaning.

5.4.2 Onboarding

To introduce the visualization scheme and the platform features to the platform users, we followed the strategy of onboarding. Onboarding is typically applied in game design and means to make users gradually familiar with the features of a game. On the GARUSO platform, we applied two different onboarding strategies. The platform users are closely guided until they have rated and shared a post for the first time.[4] During this time, the basic *requirements features* and GUI elements are explicitly introduced to them. After this novice phase, we used expertise levels to steer the introduction of additional *requirements features* and the completion of the GUI. For further support, the platform provides (1) short information on the GUI elements when moving the mouse pointer over them or when tapping on them on mobile devices; (2) an FAQ page; and (3) a contact form to get in touch with the administrator.

[4] An example of the onboarding of novice users is available here: https://figshare.com/s/e231f59d1fc0d828ba7f.

5.4.3 A sample usage scenario

In this subsection, we describe a sample scenario how user *bulb*, who is on expertise level IV, interacts with the GARUSO platform. Figure 8 shows the main page of the platform that she sees after logging in. The top navigation bar enables her to access all other pages of the GARUSO platform, to view the page content in another language and to log out. Furthermore, she can support the identification of unidentified stakeholders with the share buttons of the social media channels, which are displayed on the right. With respect to activities facilitated by the *requirements features*, she sees her missions in the left sidebar and her status in the right sidebar. The center part of the main page shows the posts in the upper part with statistical information below. The information on her missions shows that she needs, for example, four additional evaluation points to reach level V. As the paw icon is on a green background, she can earn them with any evaluation activity, which supports her autonomy. Right below she sees the activities needed to master the basic challenge ("Shape Wishes"), which she selected. Based on the visualization scheme (see Fig. 7), the wand icon on purple background shows that 18 sharing points are needed due to the explicit sharing of posts. *Bulb* can also select an advanced challenge ("Benefit Challenges") from the drop down list, which she has not done yet. According to her status information, she earned 30 community points and three badges, among which two were also earned by 13 other platform users. Between the sidebars, the statistics reveal that the other platform users are on average more active except for evaluation activities and that two of them are on her expertise level. Right above are two carousels. The upper one shows truncated versions of posts in groups of three and the lower one additionally displays the images used in posts in groups of four. User *bulb* can switch back and forth the carousels with the arrow icons. The buttons above enable her to filter the carousel entries. For example, a click on the yellow *voted* button will limit the entries to posts which have sub-post that she already voted. When she clicks on a carousel entry, she gets to the detailed view of a post (see Fig. 9). The wish part and the benefit part of the post are split and followed by a list of sub-posts. The shown post has one sub-post. Here, *bulb* can evaluate the shared contributions and share additional sub-posts, which she has not done yet.

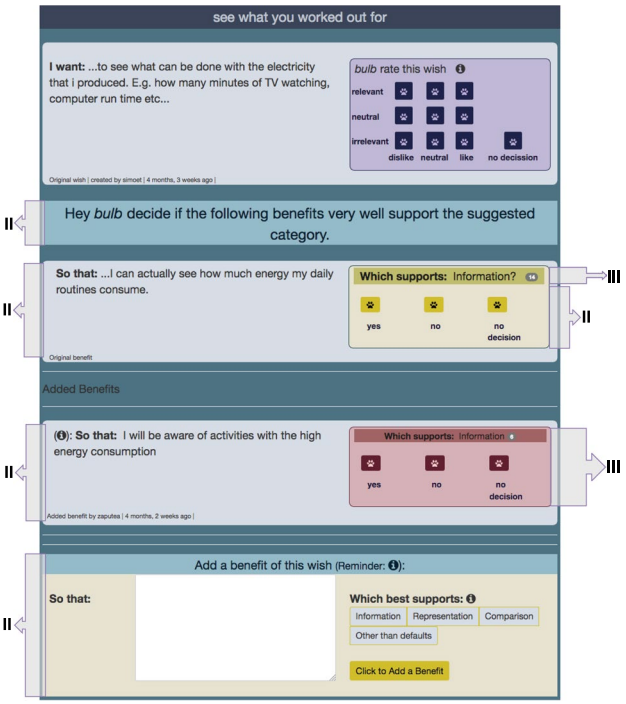
5.5 Implementation

The GARUSO platform facilitates device independent, multi-language, asynchronous communication among its users. We developed a responsive design that considers the screen size of the accessing device to support desktop and

Fig. 8 A screenshot of the main page of the GARUSO platform shown to user *bulb* (who currently is on expertise level IV). The roman letters (I–IV) show the expertise level on which a GUI element of a feature became visible to bulb (see Fig. 6b for the complete feature list for expertise levels I–V)

mobile devices alike and applied Google Translate[5] to support multiple languages. On social media platforms, content that is shown at the beginning of a list typically gets the most attention by the users. To address this fact, we developed an automated process that randomly orders the list of posts over time. The features of the *RE engine* can be used simultaneously and asynchronously by the platform users. To prevent inconsistent states of existing ratings and votes, already

[5] https://translate.google.com/.



The wish-part of the post is on top, followed by its benefit-part and a sub-post. The roman letters indicate the expertise level on which a GUI element becomes visible. Note that only the central part of the screen is shown. The top bar and the two sidebars (see Fig. 8) have been omitted to save space.

Fig. 9 A screenshot of the detailed view of a post on the GARUSO platform

shared (sub-) posts cannot be edited or deleted, which furthermore prevents cheating.

The GARUSO platform has been implemented with Python 3.4 and the database PostgreSQL 9.4. For the Web framework, we considered Django 1.8[6] and Bootstrap 3.3.[7] Furthermore, we used FontAwsome[8] for the GUI icons and ShareThis[9] for the social media share buttons.

6 Evaluation of the GARUSO approach (RQ3)

In this section, we describe an empirical study that we conducted to evaluate the GARUSO approach. The software system, for which the platform users participated in the elicitation and prioritization of requirements, was the one of the SmaWoMo system that we described in Sect. 2.4.

The study results contribute insights in the domain of crowd RE with focus on the identification and collaborative participation of stakeholders outside organizational reach. With the identification strategy, we attracted 726 visitors from around the world to the GARUSO platform. 244 of them are considered potential stakeholders and 63 stakeholders. During the study period, 32 stakeholders actively participated on 49 days on the GARUSO platform, conducting a total of 504 interactions related to requirements elicitation and prioritization.

6.1 Study design

We ran the study for 92 days from September 2, 2017 to December 2, 2017. The platform was online available over the entire 92 days during which visitors could register and consecutively participate in the platform activities. Until day 47, we occasionally injected information. Table 5 summarizes these actions in chronological order.

The study started when the first author of this article shared three initial posts on the GARUSO platform. To identify stakeholders of the SmaWoMo system and attract them to the GARUSO platform, we considered the lessons we learned in the study on stakeholder identification (see Sect. 4.9). We used the SNSs Facebook, LinkedIn and Xing and considered the online advertisement channel Google AdWords, as well as the e-mail list used in the study described in Sect. 4, an e-mail list on ICT and sustainability and the Empa intranet. Furthermore, we used the advertisements of Hans (achiever) and Zoi (explorer) (see Fig. 1).

We distributed the advertisements eleven times on Facebook, eight times on LinkedIn and seven times on Xing between day six and 14, and again once on day 40 on Facebook and LinkedIn. On day 12, an e-mail with information on the elicitation of requirements for SmaWoMo on the GARUSO platform was distributed through UZH's official mailing service to about 26'000 students and staff of the University of Zurich. We started our AdWords Campaign on day 17 with a budget of 80 USD. Furthermore, we accepted the offer of an administrator of a newsletter on various topics on "ICT and sustainability" who asked if we would like to announce the possibility to contribute requirements for the SmaWoMo system on the GARUSO platform. The newsletter with this announcement was sent on day 19 to the about 380 subscribers.

Furthermore, we kept the stakeholders who participated on the GARUSO platform informed about the overall platform activities. This approach is typically applied with automated processes by service providers to keep their customers in the loop. The GARUSO platform is, however, a prototype, which is why we did not implement such a service but manually distributed e-mails. We sent a total of six notification e-mails to the registered platform users.

Every e-mail summarized the activities of the week and compared them with the ones of the previous week. For example, we included information on the numbers of new

[6] https://www.djangoproject.com/.
[7] https://getbootstrap.com/.
[8] http://fontawesome.io/.
[9] https://www.sharethis.com/.

Table 5 The interactions we took during the study

Day	Date	Interaction
1	2017-09-02	Study start
6	2017-09-07	Advertisement published once on Facebook (public thread)
7	2017-09-08	Empa published an advertisement on its intranet
10	2017-09-11	Advertisement published eight times on Facebook (once on public thread; seven times in groups)
11	2017-09-12	Advertisement published once on Facebook (in group)
12	2017-09-13	Advertisement published once on Facebook (public thread) and e-mail sent to UZH students and staff members
13	2017-09-14	Advertisement published three times on LinkedIn (in groups) and seven times on Xing (in groups)
14	2017-09-15	Advertisement published five times on LinkedIn (once on public thread; four times in groups) and information e-mail no. 1 sent to platform users
17	2017-09-18	Started AdWords campaign
18	2017-09-19	Information e-mail no. 2 sent to platform users
19	2017-09-20	Information distributed to subscribers of a newsletter on sustainability
25	2017-09-26	Information e-mail no. 3 sent to platform users
31	2017-10-02	Information e-mail no. 4 sent to platform users
40	2017-10-11	Advertisement published once on Facebook (public thread) and once on LinkedIn (public thread), and information e-mail no. 5 sent to platform users
47	2017-10-18	Information e-mail no. 6 sent to platform users
92	2017-12-02	Study end

registrations and shared (sub-) posts. In the e-mails, we also invited the users to further participate on the GARUSO platform. However, we never coerced them nor offered them any incentives other than those from the *gamification engine* of the GARUSO platform (see Sect. 5.3).

To reduce the risk of malicious and fake users such as bots, we applied a two-way and three-step registration process: The visitors needed to: (1) provide a nickname and their e-mail address; (2) activate their registration with the link sent to the provided e-mail address; (3) create a user profile on the GARUSO platform by answering some questions, for example, about their age and the online channel through which they first accessed the GARUSO platform. All answers were voluntary except the one about the initial access channel. Only the visitors who completed all three steps were enabled to participate in the RE activities on the GARUSO platform.

At this point, the platform users were, however, not familiar with the platform features, which bears the risk of overwhelming them. Overwhelmed users tend to quit or to be unaware of the full potential of a tool. To mitigate this risk, the GARUSO platform employs an explicit onboarding strategy (see Sect. 5.4.2).

6.2 Evaluation goals and metrics

The goal of our evaluation was to study if the GARUSO approach is able to attract a crowd of stakeholders outside organizational reach and can motivate them to participate voluntarily to the elicitation and prioritization of requirements on the GARUSO platform.

We recorded all user activities over the entire duration of the study with algorithms that we developed for this purpose. In addition, we used Google Analytics[10] to track the visits to the GARUSO platform. The monitored data were stored in a local database maintained by the authors and by Google, respectively. We used both data sets for subsequent quantitative analysis.[11]

A qualitative analysis of the data is beyond the scope of this paper and part of future research. However, the user stories contributed on the GARUSO platform actually provide useful contributions to the elicitation of requirements for the SmaWoMo system. They reveal a tendency toward two approaches on how to support the SmaWoMo: *learning approaches*, in which the amount of produced electricity is compared to known activities and *playful approaches*, in which the physical energy is used to perform specific activities in the virtual world. We provide a sample of seven user stories at https://figshare.com/s/55517ef8416424362f7d. All of them were shared by different platform users. Overall, we did not find any badly written user stories. However, we observed different lengths and abstraction levels of user stories. In particular, the latter indicate the need for measures that consider the stakeholders' domain knowledge in the rules that define the criteria to reach upper levels (see design principle #12 in Table 12).

For the quantitative evaluation of the results, we applied the following metrics.

1. *Visitor involvement:* To define how involved the platform visitors' are with respect to the RE process for the SmaWoMo system, we measured the frequency and time during which the visitors interacted with the platform. With respect to previous research [53], which found that

[10] https://analytics.google.com.

[11] The data used for the quantitative analysis is available at https://figshare.com/s/00cd571cf8cd67a207fb.

people need ten seconds to be convinced to remain on a website, we defined visitor involvement as follows:

- *Lowly involved visitors* are visitors who interacted less then ten seconds with the platform;
- *Moderately involved visitors* are one-time visitors who interacted ten or more seconds;
- *Highly involved visitors* are returning visitors who interacted more than ten seconds per visit.

To know the visitor involvement supports the evaluation of the identification strategy.

2. *Stakeholders:* As stakeholders outside organizational reach are not known in advance, we need to define when we consider a visitor of the GARUSO platform to be a stakeholder. Obviously, only visitors who performed some serious activity on the platform can be considered stakeholders. For our study, we decided to use the following metrics for stakeholders of the SmaWoMo system:

   - Moderately or highly involved visitors are considered *potential stakeholders*;
   - Potential stakeholders who completed the three-step registration process on the GARUSO platform are considered *stakeholders*;
   - *Active Stakeholders* are stakeholders who conducted at least one activity on the GARUSO platform that supports the RE activities.

3. *Stakeholder participation:* To measure this metric, we count the RE activities on the GARUSO platform and consider the number of days during which the activities were taken.

The number of stakeholders helps to understand the effectiveness of the *identification strategy*. With our definition of active stakeholders, we are consistent with previous research on crowdsourcing [28] that considers users engaged if they take one context-related activity. The ratio of active stakeholders vs. stakeholders adds insights to better assess the design choices of the onboarding process. The stakeholder participation is a means to investigate the effectiveness of the GARUSO platform with respect to the *motivation concept*.

6.3 Data analysis

We analyzed the data in four ways:

(1) To evaluate the identification strategy, we used the information tracked with Google Analytics that we first cleaned from spam and bot entries with features provided by Google Analytics. Consecutively, we selected the filter criteria *new users*, which in Google Analytics describes first-time users, and *session*, which defines user interactions, such as, page views on the monitored website within a time frame. To set the time frame, we used the metric on stakeholder involvement that we described above. For example, to calculate the number of visitors with low involvement, we looked for new uses who had one or multiple sessions, with a duration of less than ten seconds each (see Fig. 10). Google Analytics monitors, however, traffic sources. Based on their definitions,[12] we map them to the online channels used in our identification strategy (see Fig. 10c).

- *Mapping 1:* access through the distribution by e-mail is included in direct traffic.
- *Mapping 2:* access through our Google AdWords campaign is included in traffic from display networks[13] and paid search.
- *Mapping 3:* access through the Empa intranet is included in traffic from referrals.

(2) We calculated the number of potential stakeholders, stakeholders and active stakeholders (see Table 6). For the latter two categories, we considered the data they provided during their registration process to investigate demographic aspects (see Table 8) and their domain knowledge (see Fig. 11).

(3) In terms of stakeholder participation, we plotted the values of the platform activities for the entire time of the study (see Fig. 12) and analyzed them with respect to the stakeholders' login activities (see Table 9) and RE activities (see Table 10).

(4) We complete the analysis on the active stakeholders' participation with the evaluation of their feedback (see Figs. 13 and 14).

6.4 Results

In this subsection, we present the results of our evaluation study and discuss the findings.

6.4.1 Key figures

Table 6 summarizes our results. It highlights the key numbers and provides pointers to the subsections, tables and figures where we present the details.

6.4.2 Key findings on stakeholder identification (SI)

In this subsection, we present and discuss our key findings on the effectiveness of the identification strategy.

[12] https://support.google.com/analytics/answer/6205762.

[13] https://support.google.com/adwords/answer/2404190.

Table 6 Overview of key figures

Platform visitors (see Table 7 and Fig. 10)		726
Potential stakeholders (see Sect. 6.4.2)		244
Stakeholders (see Sect. 6.4.3)		63
Active stakeholders (see Sect. 6.4.3, Table 8, and Figs. 10 and 11)		32
Users per expertise level (finally reached level; see Table 10)		I: 19; II: 3; III: 6; IV: 2; V: 2
User activities	Total	Avg./User
Duration of participation (days from registration to last activity; see Table 9)	418	13.1
Number of logins (see Table 9)	177	5.5
Viewed posts (see Table 9)	468	14.6
Shared posts (see Table 10)	37	1.2
Shared sub-posts (see Table 10)	19	1.5
Ratings (see Table 10)	288	9
Votes on posts (see Table 10)	141	10.9
Votes on sub-posts (see Table 10)	19	1.9

Table 7 Summary of the platform visitors' involvement

Visitors with low involvement	482 (66.4%)
Visitors with moderate involvement	175 (24.1%)
Visitors with high involvement	69 (9.5%)
Total platform visitors	726 (100%)

KF_SI 1: Every third visitor is a potential stakeholder. Table 7 presents the results based on the metric on user involvement. It reveals that overall, the GARUSO platform had 726 individual visitors. 482 (66.4%) of them had a low involvement compared to 244 (33.6%) of whom 175 (24.1%) were moderately involved and 69 (9.5%) highly involved. As defined above, we regard the moderately or highly involved visitors as potential stakeholders of the SmaWoMo system.

Discussion: Taking the metric of visitor involvement into account, it becomes clear that *lowly involved visitors* had not the time to register on the platform. Therefore, we do not refer to them as potential stakeholders for SmaWoMo. In fact, it is rather likely that they clicked on the link to the GARUSO platform because they expected different contents. In contrast, *moderately involved visitors* as well as *highly involved visitors* had the time to register on the GARUSO platform. However, the data do not reveal whether they actually did so. Thus, they might also have quit or started the registration process without completing it, for example, because they were interrupted or could not spend the entire time needed to complete it. Either way, their level of involvement indicates that they had some interest for SmaWoMo. Therefore, we consider them potential stakeholders.

In summary, the data show that one-third of all visitors are potential stakeholders for SmaWoMo. This is consistent with the previous research results [28] on crowdsourcing.

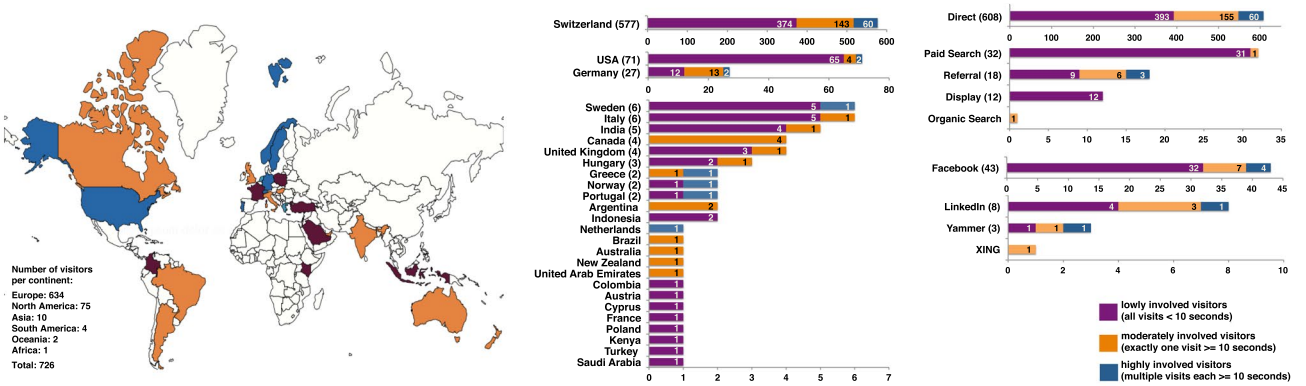
KF_SI 2: The visitors accessed across all continents with regional differences. Figure 10a, b illustrates from where the GARUSO platform was accessed. The results show that the visitors accessed from 27 countries around the globe and across all continents, but with regional differences. In fact, 97.7% (709) of all visitors accessed the GARUSO platform from countries in Europe and North America. With 577 visitors (79.5%) the majority accessed from Switzerland followed by the USA with 71 (9.8%) visitors, and Germany with 27 (3.7%). In contrast, only one visitor (0.1%) accessed from an African country.

Discussion: The results can partially be explained with digital inequality, i.e., the unequal distribution of internet access among countries [51]. Internet censorship, which is practiced in some countries, might also have an influence. Moreover, previous research indicates that the size of individual networks on SNS differs across cultures [31]. This suggests that the online channels, which we used for the purpose of stakeholder identification, affect our results in terms of countries of access. Another factor might be that the topic of the SmaWoMo project is not perceived to be important in certain cultures.

With respect to Switzerland, which is an outlier considering the number of visitors, the results are probably influenced by the fact that the SmaWoMo project is conducted in Switzerland and both UZH and Empa are Swiss research institutions. Moreover, the stakeholder identification was initiated in Switzerland, which is potentially important to consider as SNS algorithms decide what information their members get to see based on marketing considerations to influence their members' activities [59]. Therefore, it is likely that the focus of the SNSs used for our study was Switzerland.

KF_SI 3: The largest sources of access are not necessarily the best ones with respect to potential stakeholders. Figure 10b, c illustrates the countries from where the GARUSO platform was accessed and the traffic sources that were used for the access. The results show that 93% (675) of the visitors accessed the GARUSO platform from the only three countries: Switzerland, USA and Germany. Furthermore, 94.1% (683) of all visitors accessed through one of three traffic sources only: direct traffic, Facebook and paid search results. However, these countries and traffic sources are not the most effective ones with respect to the relative number of potential stakeholders among the visitors.

Discussion: Overall, more than 90% of the visitors accessed the GARUSO platform through only three sources with respect to countries and traffic channels. This suggests that the efficiency of the identification strategy can be increased by focusing on a few countries and online

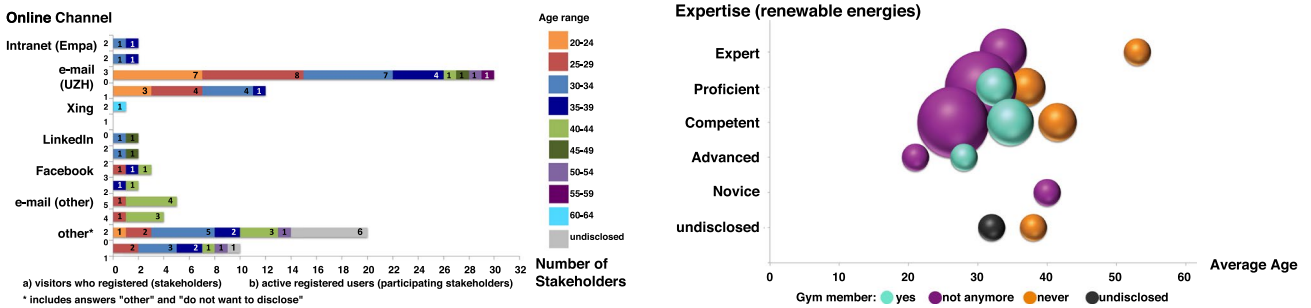


(a) Countries from where visitors accessed with respect to the maximum level of involvement

(b) Number of visitors per country and level of involvement

(c) Number of visitors per traffic source and level of involvement

Fig. 10 Illustration on the visitors of the GARUSO platform with respect to their level of involvement



(a) Number of stakeholders who registered (upper bar) and actively participated (lower bar) per identification channel and age range.

(b) The bubble size and color represent the number of stakeholders and gym membership, respectively.

Fig. 11 Stakeholder analysis

Table 8 Overview of the active stakeholders

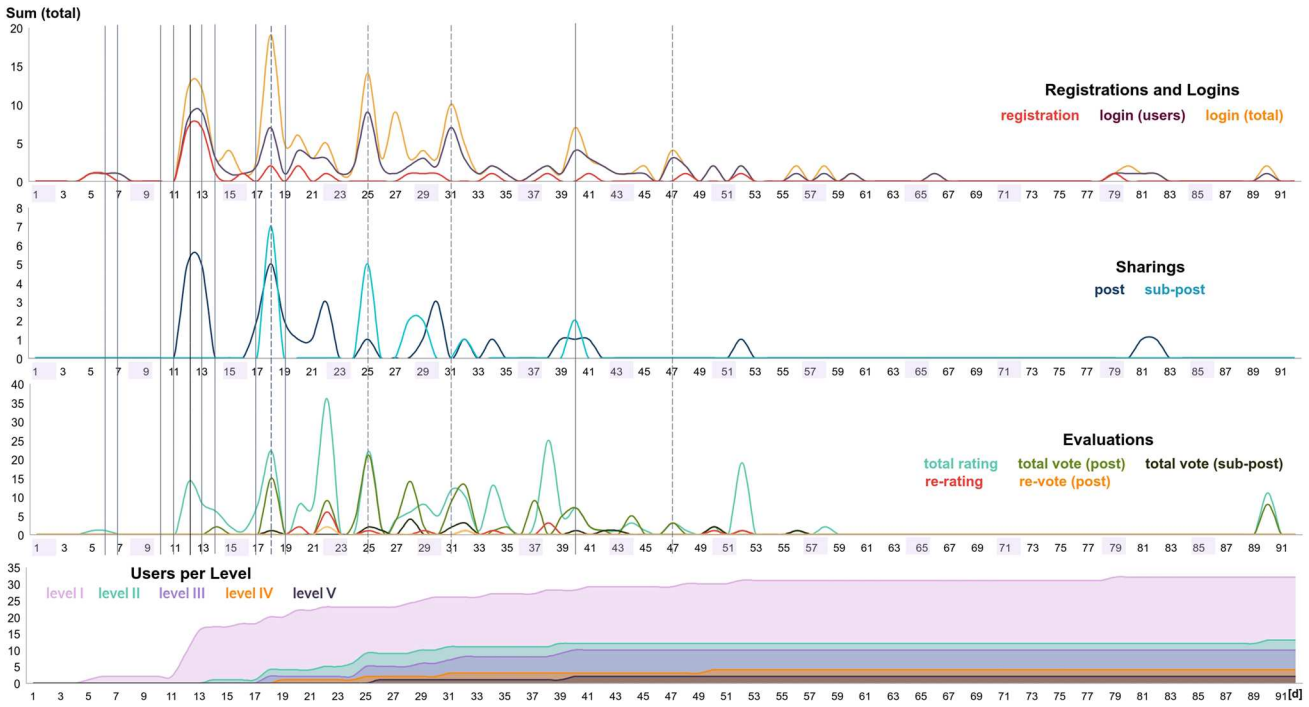
Gender: number of persons/average age	
Female	19 / 31.2
Male	13 / 34.2
Number of countries/users per continent	
Europe (CH: 13; DE: 7; IT: 4; AL: 1; CS: 1; RO: 1)	6 / 27
Asia (IR: 2)	1 / 2
North America (CA: 1)	1 / 1
South America (AR: 1)	1 / 1
Undisclosed	1 / 1

channels. However, this is only true for the absolute numbers. When considering the 18 countries with one or two visitors only, we find 11 potential stakeholders among the 23 visitors, i.e., 47.8%. In comparison, the effectiveness (rate of potential stakeholders among all visitors) for the top three countries Switzerland, USA and Germany is 35.2%, 8.5% and 55.6%, respectively. We find a similar effect for the traffic sources. For example, the effectiveness of LinkedIn is 50%, while the top three channels yield 35.4% for direct traffic, 3.1% for paid search and 25.6% for Facebook. These results suggest that diversity with respect to countries and online channels of announcing the participation in RE activities improves the effectiveness of stakeholder identification.

6.4.3 Key findings on the active stakeholders' characteristics (SC)

Next, we present and discuss two key findings about the active stakeholders of the SmaWoMo system.

KF_SC 1: Overall, stakeholder participation is above average. Any visitor of the GARUSO platform who registered on the platform is considered a stakeholder for SmaWoMo (see Sect. 6.2). Sixty-three stakeholders were identified (see Table 6), which means that about every forth of the 244 potential stakeholder (25.8%; see KF_SI 1 above) registered on the GARUSO platform. Among the registered stakeholders, 32 (50.8%) actively participated in the RE



Solid vertical lines show the activities we took for identifying stakeholders and dotted lines those for notifying stakeholders (see Table 5). Weekends are marked with colored bars along the x-axis. *total rating* and *total vote* include *re-rating* respectively *re-vote*. The colors do not have semantics.

Fig. 12 The stakeholders' activities and their levels of expertise on the GARUSO platform per day

Table 9 Summary on the stakeholders' activities (Numbers in bold indicate the highest average values per activitiy. Numbers in italics have not been evaluated.)

Self-perceived expertise: renewable energies	n[1]	Logins					Views		RE activities			
		Sum		Days		Δ Days[2]			Share[3]		Evaluate[4]	
		Tot.	Avg.[5]	Tot.	Avg.[5]	Avg.[5]	Tot.	Avg.[5]	Tot.	Avg.[6]	Tot.	Avg.[6]
Expert	4	27	**6.8**	11	2.8	4.3	60	15	13	1.9	48	7.1
Proficient	11	56	5.1	45	**4.1**	12.3	196	**17.8**	17	**3.3**	202	**39.7**
Competent	12	68	5.7	41	3.4	**17.3**	126	10.5	17	3	104	18.3
Advanced	2	2	1	2	1	1	3	1.5	2	2	1	1
Novice	*1*	*12*	*12*	*9*	*9*	*20*	*39*	*39*	*1*	*0.1*	*46*	*3.8*
Undisclosed	*2*	*12*	*6*	*7*	*3.5*	*18*	*44*	*22*	*6*	*1*	*47*	*7.8*
Total	32	177	5.5	115[7]	3.6[8]	13.1	468	14.6	56	10.1	448	81

[1]Number of active stakeholders; [2]days between the first login (registration day) and the last login on the GARUSO platform; [3]Post and sub-posts; [4]ratings and votes; [5]per stakeholder; [6]per avg. number of logins; [7]person-days; [8]per person-day

process on the GARUSO platform. This means, about half of the registered stakeholders used the RE features to share and evaluate posts and sub-posts. This is significantly higher than the average of 10% active users in online communities found in previous research by Nielsen [45]. Even if we use the 244 potential stakeholders as the basis of comparison, we get better results than those reported by Nielsen: 13.1% of all potential stakeholders participated actively.

Discussion: Nielsen [45] found that 90% of users in online communities are so-called lurkers, i.e., users who read or observe, but do not contribute actively. A study on e-mail-based discussion lists shows differences between health-related topics and topics on software support with an average of 46% lurkers and 82% lurkers, respectively [46]. More recent results in the context of Web-based knowledge transfer show even higher shares of lurkers. For example, 89% of registered users on Taskcn.com, one of the largest Witkey Web sites in China, are lurkers [63]. Witkey is a web-based system that enables its users to share and buy services and information. Furthermore, over 99% of all Wikipedia visitors are lurkers [11].

Table 10 Overview of the stakeholders' RE activities

Self-perceived expertise: renewable energies	Shared posts ❶		Shared sub-posts ❷		Ratings* ❶		Votes on post* ❷		Votes on sub-post ❸		Re-ratings ❶		Re-votes on post ❷		Stakeholders per expertise level				
	Sum	Avg.	Sum	Avg.	Sum	Avg.	Sum	Avg.	Sum	Avg.	Sum	Avg.	Sum	Avg.	I	II	III	IV	V
Expert	6	**1.5**	7	7✖	36	9	10	10	2	2	1	1			3				1
Proficient	12	1.1	5	1	125	**11.4**	68	**13.6**	9	**2.3**	8	**2.7**			6	1	3		1
Competent	11	0.9	6	**1.5**	68	5.7	31	7.8	5	1.7	2	1			8	1	1	2	
Advanced	2	1	✗	✗	1	0.5	✗	✗	✗	✗			✗	✗	2				
Novice	*1*	*1*			*30*	*30*	*16*	*16*	✗	✗	*4*	*4*	*2*	*2*		*1*			
Undisclosed	*5*	*2.5*	*1*	*0.5*	*28*	*14*	*16*	*8*	*3*	*1.5*	*2*	*1*	*1*	*0.5*				*2*	
Total	37	1.2	19	1.5	288	9	141	10.9	19	1.9	17	1.9	3	0.2	19	3	6	2	2

* includes re-ratings respectively re-votes; ✗ feature is not enabled;

❶ enabled on expertise level I; ❷ enabled on expertise level II; ❸ enabled on expertise level III.

✖ due to one participant in this category who could have performed this activity, we did not consider this average value

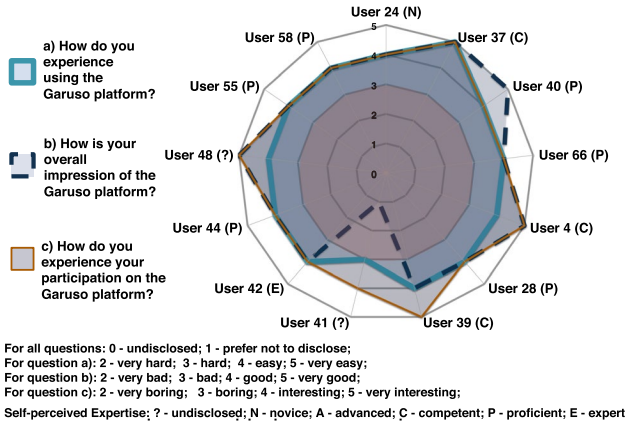
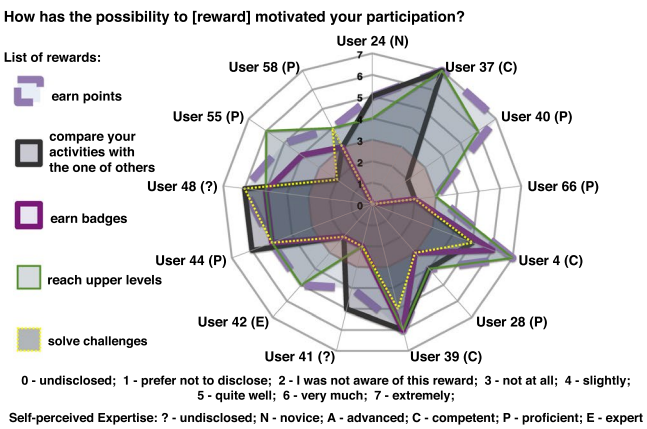


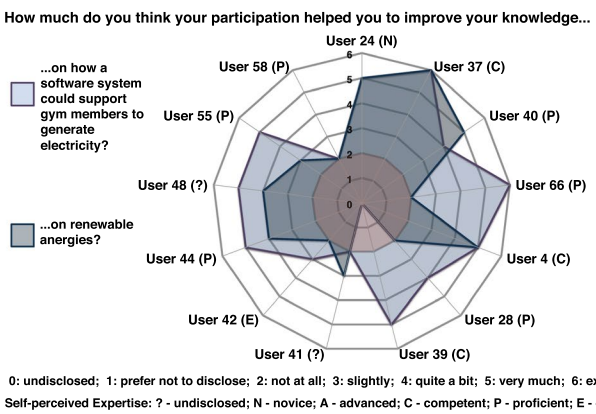
Fig. 13 Overall impression on the GARUSO platform

Similarly, the results of our study vary between the different online channels. Figure 11a shows the numbers of all registered stakeholders (upper bars) and the ones of the active stakeholders (lower bars) per channel. The results reveal that Xing, the e-mail distribution and "other" had the highest percentage of lurkers with 100%, 60% and 50%, respectively. However, these results need to be considered with caution as it is unclear which online channels were used by the stakeholders who selected "other".

KF_SC 2: The stakeholders form a knowledgeable heterogeneous crowd of participants. The results show that the active stakeholders were identified on at least five online channels and had an age range from 20 to 54 (see Fig. 11a). Their average age was 34.2 and 31.2 years for the male and for the female stakeholders, respectively, who



(a) The effects of rewards on the stakeholders' motivation.



(b) The platform users' development.

Fig. 14 Feedback on the effectiveness of the gamification engine

all together lived most of their lives in at least nine countries (see Table 8). Furthermore, they perceive their domain knowledge as rather good: Together, they have a considerable level of expertise on renewable energies and experience with going to the gym (see Fig. 11b).

Discussion: The results indicate that the active stakeholders formed a heterogeneous (i.e., diverse with respect to various aspects) and knowledgeable crowd.

The results of our study are consistent with the ones that define a crowd in the context of crowdsourcing [22]: age diversity, gender diversity, spacial diversity, expertise diversity, as well as anonymity, largeness, randomness and suitability.

With respect to age and gender, our results are also aligned with results on the demographics of participants on Mechanical Turk (turkers) [27, 50] and in Web studies [18]. The majority of participants in those studies were female (70%, 52–75% and 57%, respectively) with a similar age range (21–35 [27] and 19–34 [50]).

The 32 active stakeholders in our study do not constitute a large crowd. Therefore, our results need to be interpreted with some care. However, as they coincide with the results of other studies, we believe that our results are valid.

The criteria of anonymity, largeness, randomness and suitability mentioned by Hosseini et al. [22] are met by the GARUSO platform:

- *Anonymity* refers to not knowing each other. On the GARUSO platform, the e-mail address, which is required in the registration process, is the only means for identifying a participant. However, this information is not revealed to other participants.
- *Largeness* means in this context that the crowd is large enough to fulfill a task: There are enough active stakeholders to enable the RE process on the GARUSO platform.
- *Randomness* of a crowd exists if no criteria were established to select the crowd members. The identification strategy of the GARUSO approach focuses on some initial online channels. Nevertheless, participation on the platform is open to everyone.
- *Suitability* describes the capability of a crowd to contribute to the intended purpose. The users of the GARUSO platform indeed contributed requirements for the SmaWoMo system and supported their prioritization.

6.4.4 Key findings on stakeholders participation (SP)

Subsequently, we present and discuss four key findings on stakeholder participation.

KF_SP 1: The crowd of stakeholders participated on 49 days between day five and 90. Figure 12 shows the activities on the GARUSO platform per day. The top graph presents the number of registered stakeholders, logged in stakeholders (*login (users)*) and overall logins, which includes multiple logins of stakeholders (*login (total)*). The two consecutive graphs visualize the RE activities on sharing and evaluating posts and sub-posts. Furthermore, we show the days of the activities that we performed to identify stakeholders and inform the registered stakeholders about the platform activities (see Table 5). We use solid lines for stakeholder identification and dotted lines for stakeholder notification. To indicate the weekends, we use a darker background. Together, the three graphs reveal that the stakeholders were active from day five to 90, with increasing periods of inactivity toward the end. The longest period of continuous participation lasts five weeks between day 12 and 46 with only two days (36, 46) of inactivity. The results suggest a relation to our activities on stakeholder identification and notification. Moreover, they provide evidence that the stakeholders were motivated beyond our interactions.

Discussion: The majority of stakeholders registered around day 12 on the GARUSO platform, which is when we started the identification of stakeholders with the UZH e-mail service and on the SNSs Facebook, LinkedIn and Xing. This suggests that the stakeholders registered as a consequence of our activities on stakeholder identification. The results are, however, not as clear for most of the other days. In fact, the stakeholders typically registered several days after our activity on stakeholder identification. In contrast, the results indicate a strong relation between our activities on stakeholder notification and the number of logins. Five of the six days of stakeholder notification show a significant increase in the numbers of logins. Furthermore, the results suggest that the stakeholders were motivated beyond our interactions and independently of the day of the week to participate in the RE process on the GARUSO platform. For example, they indicate that the influence of stakeholder notifications fades over time. In fact, the curve *login (total)* decreases almost linearly from day 18 to 25 and 31 to day 40 and 47, which is similar for the curves on shared sub-post, ratings and votes on post labels. Moreover, the number of shared posts and in particular of ratings is typically higher on days between interactions than on the ones of interactions. Finally, we did not find any relation between the days of the week and the activities.

KF_SP 2: The gamification engine fosters the stakeholders' motivation to participate. The bottom graph in Fig. 12 illustrates for each study day the number of stakeholders per expertise level of the GARUSO platform. Together with the two curves on sharing and evaluating above, the results show that on the days where stakeholders reached level II or III, the number of activities that become enabled on these levels increased. This indicates that the gamification engine indeed works: The possibility to level up and be rewarded

with access to more advanced RE features helps foster stakeholder participation on the GARUSO platform.

Discussion. The reward system that we presented in Sect. 5.3 and Table 6b defines that the RE features *vote post label* and *share sub-post* are enabled on expertise level II, and *vote sub-post label* on expertise level III. The results in the bottom three graphs of Fig. 12 show that the number of the corresponding activities increased on most of the days on which stakeholders reached level II or III. For example, stakeholders reached level II on nine days (days 14, 18, 22, 24, 25, 29, 31, 39 and 90). These are also the days on which the curve that illustrates the number of votes on post labels increases, except on day 24. Similarly, the number of shared sub-post is affected. However, with only three overlapping days (18, 25 and 29) and one day of delay (40), the assumed effect of reaching level II on the number of shared sub-posts is smaller than the one on the number of votes. This difference reflects, however, the overall results, which show that the number of evaluation activities is higher than the one of shared contributions. With respect to expertise level III, we found further indications which suggest an influence of reaching a new level on the activities performed afterward. When stakeholders reached level III (days 18, 25, 29, 31, 32, 39 and 40), the curve of votes on sub-post labels increased, except on days 29 and 39.

KF_SP 3: Stakeholder participation differs with respect to perceived domain knowledge. Table 9 summarizes the results on the stakeholders' participation overall and under consideration of the stakeholders' self-perceived level of domain knowledge. To calculate the average values for the logins and views, we used the number of stakeholders per such level. Similarly, we considered the average number of logins for the activities on sharing and evaluating. Overall, the results show that on average the stakeholders logged in 5.5 times on 3.6 days over a period of 13.1 days. During this time, they viewed on average 14.6 times a post, which means that they clicked so many times on posts. Moreover, they shared a total of 10.1 contributions (posts and sub-post) and evaluated 81.0 contributions per average number of logins. With respect to the stakeholders' self-perceived domain knowledge, the results differ. The numbers in bold indicate the highest average values per activity. Due to the lack of information and only one participant, we did not evaluate the categories *novice* and *undisclosed*. We indicate this in Table 9 by typesetting these numbers in italics.

Discussion: Most stakeholders perceived their domain knowledge competent (12) or proficient (11) and only few considered it expert (4) or advanced (2). One stakeholder, furthermore, indicated to be a novice with respect to the application domain and two did not disclose any information on that matter. The results show that the maximum average values for the three categories *login*, *views* and *RE activities* appear among the stakeholders with one of the top three levels of domain knowledge. In terms of logins, on average the self-perceived experts logged in most times (6.8), the proficient ones on most days (4.1), and the competent ones over the longest period of time (17.3). It is interesting to note that in this group, the experts logged in most times, but by far over the shortest period of time (4.3). In contrast, the stakeholders with proficient domain knowledge logged in the fewest times (5.1) but distributed over most days (4.1). With respect to the number of views and RE activities, the stakeholders who considered their domain knowledge proficient were most active on average. In fact, they have the highest average number of post views (17.8) and of RE activities for both sharing (3.3) and evaluating (38.7).

KF_SP 4: The stakeholders' RE activities focused on requirements prioritization. Table 10 shows the results on the RE activities on the GARUSO platform. To calculate the average values, we used the number of stakeholders per expertise level, as presented to the right of the table. Like before, the highest average values are marked bold. As in Table 9 above, we did not consider the values in italics. Furthermore, we did not consider the average value of shared sub-posts for the expert category due to only one participant in this category who was on an expertise level where this activity could have been performed. The stakeholders performed 504 RE activities on the GARUSO platform. Thereby, they focused on evaluation activities throughout all expertise levels. Overall, the stakeholders shared 56 contributions (11.1%) and evaluated 448 ones (88.9%). With respect to the activities enabled on expertise level I, they shared 37 posts and performed 288 ratings on posts. With focus on the activities introduced on expertise level II, they shared 19 sub-posts and performed 141 votes on posts. Moreover, they voted 19 times on sub-posts, which was possible on expertise level III and above.

Discussion: In online social media-based RE processes, activities that support the prioritization of requirements such as rating and voting typically require less effort than activities for sharing content. Thus, it seems obvious that the former are performed more often than the latter on a social media platform such as GARUSO. However, previous research results do not necessarily confirm this assumption.

For example, a study on the potential of Facebook to support the elicitation and prioritization of requirements [55] shows a preference among the study participants to share posts. In fact, the evaluation of posts made only 32.8% if the participants were not explicitly asked to evaluate, and 53% if they were explicitly asked to do so. In contrast, the results of our study show a rather clear tendency toward evaluation activities. Thereby, the results of our study are consistent with the ones of a previous study on participatory RE on the online elicitation platform REfine [57].

Overall, the results of the three studies suggest that activities on requirements prioritization are more numerous

compared to the ones on requirements elicitation if the activities are performed on social media platforms that have an explicit RE purpose. However, the study results can only partially be compared with each other. For example, neither the studies on Facebook [55] nor the one on REfine [57] focused on stakeholders outside organizational reach. With a duration of two and four weeks, respectively, they were also shorter than our study. Moreover, the gamification approach of REfine [57] follows a different strategy which focuses on competition, while the one applied to the GARUSO platform uses a motivation concept that addresses several aspects of motivation and considers the stakeholders' changing experience over time. Despite these differences, we think that together the results of the three studies provide valuable insights for the future design of RE platforms.

6.4.5 Key findings from stakeholder feedback (SF)

The GARUSO platform includes a feedback form, which is accessibly via the navigation bar (see Fig. 8) to all registered stakeholders. Furthermore, the stakeholders are automatically directed to it when they reach expertise level III and V. The feedback is voluntary and free of any rewards or incentives. The feedback form includes questions and comment fields.

To be able to most accurately derive the stakeholders' attitudes, we use a semantic differential scale [49] and added an even number of scale points for questions on familiar topics [6]. On one side, we were interested in how the stakeholders experienced different aspects of usability with respect to two extremes (see Fig. 13). On the other side, we wanted to know the intensity with which they perceived their motivation (see Fig. 14a) and knowledge development (see Fig. 14b), which is why we used a one-sided semantic differential scale for those questions. Thirteen stakeholders gave feedback. Three of them were on expertise level I, one on level II and nine on level III.

In Figs. 13 and 14, we show the results. We used spider diagrams in which the concentric threads represent the scale points. The further away they are from the center, the more positive the answers. To visually separate the negative answers from the positive ones, we used a red-colored background. Furthermore, we used letters for their self-perceived domain knowledge: E, P, A and ? for expert, proficient, advanced and undisclosed, respectively.

KF_SF 1: The GARUSO platform is easy to understand and interesting to use. Figure 13 illustrates how the stakeholders perceive the GARUSO platform overall. The results show that the three evaluation criteria *usability*, *impression* and *experience* were positively rated by the majority of the stakeholders. Furthermore, the majority perceived the GARUSO platform easy to use and had a good or very good impression about it. Moreover, they experienced their participation on the GARUSO platform as interesting or even very interesting. Only one stakeholder (ID 41) perceived using the GARUSO platform as hard and preferred not to disclose an opinion on the overall impression, yet experienced the participation on the platform as good.

KF_SF 2: The rewards have different motivational effects on the stakeholders. Figure 14a shows how motivating the different rewards of the gamification engine were perceived by the stakeholders. We set the scale value for challenges and badges on *undisclosed* for the stakeholders on level I as they had no access to them. The results show that the stakeholders felt motivated by the rewards overall, but with different intensity. The most effective rewards in terms of motivation were earned points and access to upper levels followed by access to information, which enables normative comparisons. However, they were also controversial with each at least one stakeholder who perceived them extremely motivating and one who perceived them not motivating at all. In contrast, the perception about the motivational power of solving optional challenges and earning badges was more balanced between stakeholders. However, compared to the other rewards, it was lower overall. Furthermore, one stakeholder did not perceive any of the rewards motivating (ID 66) and five were unaware of some of the rewards (ID 40-42,55,66).

KF_SF 3: Using the GARUSO platform improves the domain knowledge of most stakeholders. Figure 14b shows the stakeholders' feedback on the development of their knowledge on (1) how a software system could be beneficial in the application domain,and (2) the application domain of renewable energies.

All but one stakeholders stated that their participation on the GARUSO platform improved their (self-perceived) knowledge on at least one of the two subjects. Wit respect to the first subject, the majority of stakeholders even rated the improvement as *very much* or *extremely*. Two stakeholders did not perceive any improvement of their knowledge on the potential of a software system in the application domain. Four did not improve their knowledge on renewable energies. Note, however, that all of these stakeholders initially perceived their domain knowledge proficient or expert.

6.5 Lessons learned

Table 11 summarizes the key findings of our evaluation of the GARUSO approach. The empirical nature of our study makes it impossible to statistically test the results of our evaluation. We were, however, able to compile a set of 14 design principles (DPs) based on our key findings presented above. The DPs provide guidance for how to identify stakeholders outside organizational reach and motivate them to participate in RE activities on social media-based platforms.

Table 11 Overview of the key findings

Key findings on stakeholder identification	
KF_SI 1	Every third visitor is a potential stakeholder
KF_SI 2	The visitors accessed across all continents with regional differences
KF_SI 3	The largest sources of access are not necessarily the best ones with respect to potential stakeholders
Key findings on stakeholder characteristics	
KF_SC 1	Overall, stakeholder participation is above average
KF_SC 2	The stakeholders form a knowledgeable heterogeneous crowd of participants
Key findings on stakeholder participation	
KF_SP 1	The crowd of stakeholders participated on 49 days between day five and 90
KF_SP 2	The gamification engine fosters the stakeholders' motivation to participate
KF_SP 3	Stakeholder participation differs with respect to perceived domain knowledge
KF_SP 4	The stakeholders' RE activities focused on requirements prioritization
Key findings from stakeholder feedback	
KF_SF 1	The GARUSO platform is easy to understand and interesting to use
KF_SF 2	The rewards have different motivational effects on the stakeholders
KF_SF 3	Using the GARUSO platform improves the domain knowledge of most stakeholders

We believe that these principles contribute to the field of crowd RE beyond the GARUSO approach.

Table 12 summarizes our 14 DPs. In the subsequent two subsections, we present the DPs and describe how we derived them from our key findings.

6.5.1 Stakeholder identification

The first four DPs address the identification strategy for stakeholders outside organizational reach.

With **DP 1**, we consider that the identification of stakeholders outside organizational reach is most effective for online channels which by their nature address existing communities. This is, for example, the case with SNS groups or mailing lists (KF_SI 1-3).

DP 2 refers to the tendency that the use of diverse online channels increases the heterogeneity of the crowd of participating stakeholders (KF_SI 1-3).

Using diverse online channels requires, however, more resources than focusing on just a few channels. Hence, **DP 3** suggests to consider few, but popular online channels if the focus is on the number of identified stakeholders rather than on their heterogeneity, or if resources are scarce (KF_SI 3).

Furthermore, **DP 4** considers the circumstance that the frequent application of the identification strategy during the entire RE process supports the effectiveness of the RE process over time (KF_SI 1).

6.5.2 Stakeholder participation

To facilitate the collaborative participation of stakeholders outside organizational reach in RE activities, we suggest ten DPs (DP 5 - DP 14).

The stakeholders continuously participated over an extensive time span in the RE process on the GARUSO platform (KF_SP 1). This indicates a successful identification strategy. We assume that the registration process repelled potential malicious users, which positively affects the participation. With **DP 5**, we, therefore, suggest a strong registration process similar to the two-way and three-step process that we applied in our evaluation study (see Sect. 6.1).

DP 6 considers that the stakeholders were motivated by the notification messages that we sent to inform them about the state of the RE process (KF_SP 1).

Finding KF_SP 2 suggests that the GARUSO approach successfully motivated the stakeholders to collaboratively participate in the RE activities over time. With **DP 7**, we consider the indicated relation between the expertise levels and the platform activities (KF_SP 2 and KF_SF 2), as well as the one between the expertise levels and the stakeholders' increased domain knowledge (KF_SF 3).

The participating stakeholders were highly diverse in terms of demographics and domain knowledge (KF_SC 2, KF_SP 3), and their feedback shows that they perceived the single game elements to be differently motivating (KF_SF 2). These results indicate that the GARUSO platform successfully considers and addresses the heterogeneity of stakeholders outside organizational reach. With **DP 8**, we, therefore, suggest the use of game elements which respect different player types to improve individual playful experiences, and which are not mandatory to level up.

In terms of usability, the majority of participating stakeholders who provided feedback stated that the platform was easy to use (KF_SF 1). We assume that the reasonable application of points supports the usability of the platform, which we address with **DP 9**.

Furthermore, with **DP 10**, we consider the adapted structure of user stories to successfully support the usability of the GARUSO platform. On one side, it is simple to understand (KF_SF 1). On the other side, it reflects the collaborative nature of the platform (KF_SP 4).

Some stakeholders did not actively participate in the RE activities on the GARUSO platform after their registration (KF_SC 1). One reason for their passivity might be the onboarding process. Onboarding is, however, required to ensure equal knowledge about the RE platform among the participating stakeholders. Yet, we think if the stakeholders

Table 12 Overview of proposed design principles

#	Design principles for stakeholder identification	Influenced by KF
1	Focus on online channels, which by their nature address existing communities	SI 1-3
2	Use diverse online channels to increase the heterogeneity of the stakeholder crowd	SI 1-3
3	Use popular online channels to increase the crowd size or if you cannot afford high effort	SI 3
4	Run the identification strategy several times during the RE process	SI 1
#	Design principles for the RE platform	Influenced by KF
5	Create a strong registration process	SC 1-2; SP 1
6	Implement a newsletter service that regularly informs the stakeholders on the RE process	SI 1
7	Apply levels of expertise that gradually introduce RE features as reward for participation	SP 2; SF 2-3
8	Apply different game elements that consider the player types and are not mandatory to level up	SP 3; SF 2
9	Use points reasonably	SF 1
10	Apply a content structure where posts present simplified user stories and sub-post extend them	SF 1; SP 4
11	Provide different means to introduce the RE platform to the stakeholders	SC 1
12	Consider the stakeholders' domain knowledge in the rules that define the criteria to reach upper levels	SC 1
13	When defining the rules for reaching upper levels, consider which RE activities can actually be performed	SP 4
14	Provide a visual summary of all new features and rules when entering a new expertise level	SF 2

can choose how to learn about the platform features, they are more likely to finish the onboarding process, which we express with **DP 11**.

Similarly, some stakeholders with a high self-perceived domain knowledge stopped their participation, while they were on the first two levels (KF_SP 4). We assume that one reason for their dropout is the restricted access to RE features on these levels. In fact, the limited access hinders these stakeholders to fully apply their knowledge. However, knowing the application domain is different from understanding the platform features and the participating community. We, therefore, suggest with **DP 12** to keep the concept of expertise levels for all participating stakeholders but to consider the domain knowledge in the rules that define the criteria to level up.

The participating stakeholders focused on evaluation activities (KF_SP 4). However, these activities depend on the availability of shared posts and sub-posts. In fact, the number of shared posts sets the limit for the number of ratings that a stakeholder can perform. We address this aspect with **DP 13**, which proposes to also consider if it is possible at all to perform an RE activity for the criteria that need to be fulfilled to level up.

Finally, to ensure that the stakeholders are aware of all opportunities provided per expertise level, **DP 14** suggests to visualize all the features that are newly introduced on a level at the moment when accessing a level for the first time.

6.6 Threats to validity

In this section, we discuss relevant threats to the validity of our study according to the categorization by Wohlin et al. [61]. With respect to stakeholder identification, we perceive the same threats as discussed in Sect. 4.8. This is why we focus on stakeholder participation.

Internal validity: The empirical nature of our study limits its internal validity as it inhibits the control of potentially confounding factors. A possible threat is that the majority of stakeholders who participated in the RE activities on the GARUSO platform were identified through a single channel (the e-mail distribution). However, we do not consider this a major threat of selection as participation was anonymous and voluntary and the overall crowd was highly heterogeneous. Yet, since participation was voluntary, the results on the effectiveness of the gamification engine to motivate stakeholders could be biased due to the intrinsic motivation of the participating stakeholders. Intrinsic motivation is, however, a prerequisite of gamification. Therefore, we do not consider this a major threat. Furthermore, we believe to have addressed the threat of history as the study lasted for three months.

External validity: The effects caused by game elements (and by the algorithms controlling them) depend on the context in which gamification is applied. Therefore, the results of our study cannot just be generalized to other fields. Due to the similarity of context, our results might be generalizable to crowd RE, at least to some extent. Furthermore, we cannot exclude that some participants might not have been stakeholders, but contributed to the study in order to support our research. This threat is partially addressed by the design of the registration process. Furthermore, due to the extensive duration of the study, we do not consider this a serious threat as it is rather probable that potential *non-stakeholders* dropped out at early stages.

Construct validity: One potential threat is the absence of a ground truth against which we could evaluate the results of our study. To address this threat, we used the results of the monitored activities on the GARUSO platform and the ones of the participants' feedback for the subsequent analysis and compared them where possible with study results of related research fields. Therefore, we do not consider mono-method bias a major threat. However, to completely mitigate this threat, the results need to be compared with the ones of further studies conducted with the GARUSO approach. To address possible evaluation stress, we assured all platform users that their data were treated confidentially and evaluated for research purposes only. Furthermore, the GARUSO platform provides multi-language support to address potential language barriers. Another possible threat is given by social niceties, which have might have biased the platform users' feedback. However, the platform users did neither gain anything for giving positive feedback nor lose anything for a negative one. Therefore, we do not consider this aspect a major threat. Similarly, malicious platform users who would have wanted to cheat the system might have influenced the number and values of ratings and votes. This could potentially have slowed down the other platform users to level up and eventually demotivated them. We addressed this threat with the registration process. Furthermore, we did not observe any signs of malicious activities on the platform.

Conclusion validity: We addressed measure reliability with the onboarding process (see Sect. 5.4.2) that ensures equal knowledge of the platform users with respect to the basic features of the GARUSO platform. The point and reward systems of the GARUSO platform are based on a sophisticated motivation concept and do not just reward the collection of points. Hence, we do not consider "pointification"—the inflation of points—as a major threat. We limited the risk of wrongful evaluations by allowing the platform users to change their ratings and votes at any time and randomized the order of shown posts to prevent that new posts are always shown first. Furthermore, we evaluated a large number of data points. We monitored every activity on the GARUSO platform over 92 days and asked the platform users about their subjective feedback on different aspects of the GARUSO platform. The evaluation of both data sets shows consistent results. Moreover, the platform users could participate at any time and from anywhere. In particular, the responsive design of the GUI, which considers the screen size of the accessing device, enabled them to participate on the GARUSO platform with desktop and mobile devices alike. In terms of random heterogeneity of the participants, this is actually what we wanted: Stakeholders outside organizational reach are, due to their nature, a highly heterogeneous crowd of people.

7 Conclusions and future work

We have presented GARUSO, an approach for involving stakeholders outside organizational reach in the collaborative elicitation and prioritization of requirements. GARUSO uses gamification for attracting stakeholders and motivating them to contribute.

To evaluate our approach, we performed a field trial over a period of three months. The results indicate that the GARUSO approach actually works. We attracted visitors from all over the world to the GARUSO platform, resulting in the identification of a crowd of 63 stakeholders outside organizational reach. More than half of them actively contributed. Our evaluation also provides initial evidence that gamification can be applied effectively for motivating the identified stakeholders to participate in collaborative online RE processes. Further, our results highlight the importance of a customized motivation concept as a foundation for the gamification approach. Finally, we have derived a first set of design principles which may serve as guidance for how to identify and motivate stakeholders outside organizational reach in the context of crowd RE.

Future work is needed to assess the efficiency of the RE processes enabled by GARUSO, the quality of the resulting requirements and the limitations of the approach. We plan to study these issues and also encourage other researchers to try and further evolve the GARUSO approach.

Moreover, the GARUSO platform is still a prototype and as such provides room for improvements. A future implementation could, for example, consider the role of the platform users as they perceive it when performing an RE activities. To preserve the user-friedliness of the GARUSO platform, we suggest that the platform users are able to change their role at any time.

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